GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

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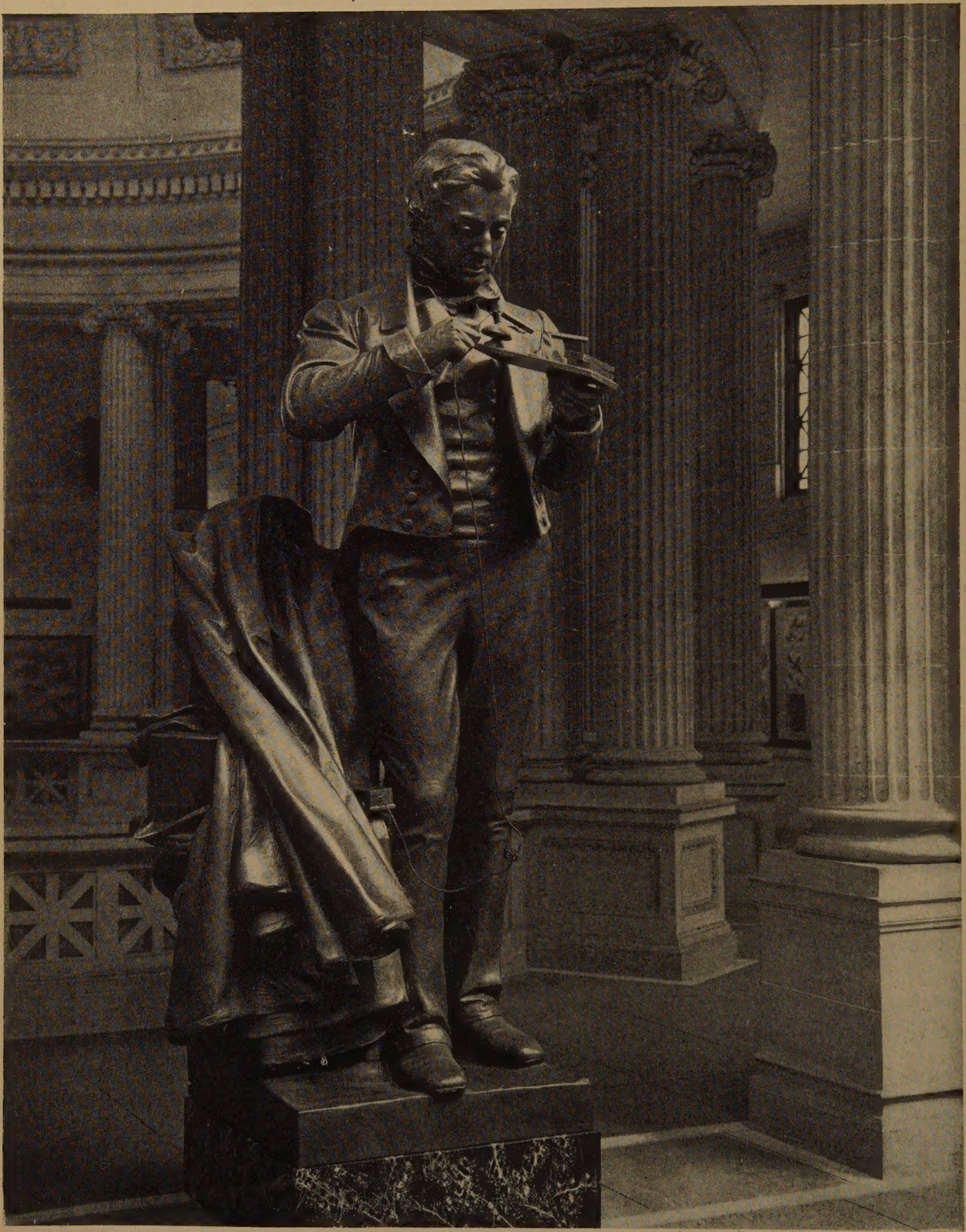


JOSEPH HENRY

Plaster-of-paris Statue of America's Famous Scientist, in the New York State Museum, Albany, N. Y. Funds are being raised to cast this statue in bronze and place it in front of the Albany Academy where Henry did so much of his famous work. (See page 85)

GENERAL ELECTRIC
REVIEW

70,000 HORSE POWER

The largest hydro-electric generating unit in the world was put into operation recently at the plant of the Niagara Falls Power Company. This single unit has the extraordinary capacity of 70,000 horse power. The electric generator is rated at 65,000 kilovolt-amperes or 52,000 kilowatts with an 80 per cent power-factor.

It is hard for even the engineering mind, and still more difficult for the lay mind, to comprehend or visualize what these figures mean.

When we say that a machine is a 70,000 horse power unit we mean that it is capable of doing two billion three hundred and ten million (2,310,000,000) foot-pounds of work in one minute.

In other words, our machine is capable of lifting a weight of one pound through a vertical distance of two billion three hundred and ten million feet in one minute, or perhaps it is more impressive to say that it will lift the same weight through a distance of 427,500 miles in the brief space of one minute.

Now the moon is 237,519 miles from the earth, so our machine generates sufficient energy to lift a weight of very nearly two pounds through a distance equal to that from the surface of the earth to the moon during every minute it works. Given one hour to do the job, it could raise a bag of coal, weighing approximately 120 pounds from the earth to the moon.

The *U.S.S. Colorado*, the pride of the American Navy and the biggest fighting ship in the world, weighs 36,000 tons. But our Niagara giant, destined to generate power for peaceful purposes only, could pick up the pride of the sea—guns, armor plate, equipment, and crew, all complete—and raise it 32 feet out of the water in one minute! Give our peace giant an hour and it could lift our greatest war giant out of the water and place it high and dry on top of a mountain 1920 feet above the sea level.

The worst of such illustrations is that they always lead us into the realm of things we do not want to do. No one wants to lift a one pound weight through a vertical distance of nearly half a million miles, and lifting battleships to the top of mountains is a pastime that no one indulges in.

So let us try again: The great purpose of a machine is to do the work that man cannot, or does not, want to do—the purely mechanical labor of raising weights, digging ditches, and in general the back-breaking work that requires brawn rather than brains. But the machine we are considering can do more than this; besides its ability to perform this purely mechanical work the energy it generates can be converted into heat energy and light as well as mechanical energy.

Let us consider its equivalent in man-power for mechanical work only. The best authorities reckon that an average man, that is a man of average strength, can perform $^1/_{10}$ to $^1/_{14}$ of a horse power of work. So our 70,000 horse power machine represents at least 700,000 men. But our machine works 24 hours a day and man works but eight, so we must now multiply by three. Our Niagara generator now represents the work of two million one hundred thousand men working on three eight-hour shifts per day.

A machine does not rest during 52 Sundays per year nor take the holidays customary with human beings, nor lay off for sickness. So, if we take all the limitations of man when considering him purely as a machine we should find that our 70,000-h.p. generator is capable of exerting a continuous mechanical effort equivalent to that of approximately three million men; because man cannot exert his maximum effort continuously for even eight hours.

This surely does mean something to us, and this fabulous amount of energy is being generated by one unit from the waters that would be running to waste if man had not harnessed them.

It is the taking of this energy from running water or from burning coal instead of from the muscles of men that is enabling us to build our civilization, to live better lives, and to become better educated, and that is therefore enabling man to do better and greater things.

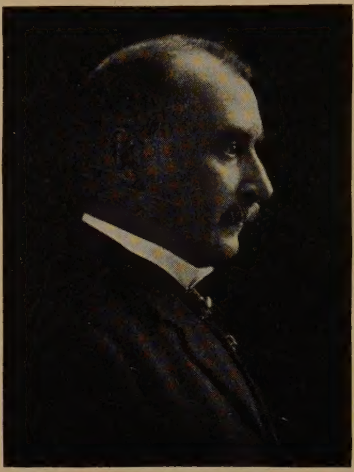
J. R. H.

San Francisco's Hetch Hetchy Water Supply and Power Development

By M. M. O'Shaughnessy

City Engineer, San Francisco

The author gives a description of the Hetch Hetchy Development as a whole and explains the San Francisco water situation. He then takes up some features of the hydro-electric development. It is interesting to note that when completed the great dam described will be the highest in the world. This dam is to be known as the O'Shaughnessy Dam as a tribute to the engineering ability of the author of this article.—Editor.



M. M. O'SHAUGHNESSY

City Engineer of San Francisco, Under Whom the Hetch Hetchy Project is Being Designed and Built

The City of San Francisco is bounded by water on three sides; to the west is the Pacific Ocean, to the north the Golden Gate connecting the Pacific Ocean with San Francisco Bay, which lies to the east of the City. This water is all salt, necessitating the importation of almost all domestic water used within the city. San Francisco now has a population of 600,000 people, and there is a marked growth of the industrial and shipping development of the city, which brings with it additional demands for water.

Many years ago the demand for water exceeded the amount which could be obtained from sources within 25 miles of San Francisco. At the present time the largest part of the water used in San Francisco is brought from the easterly side of the Bay by the Spring Valley Water Company, which is the local corporation supplying all of the water used in the city. The capacity of this company's supplies will very likely be reached within ten years if San Francisco continues to grow at its present rate.

Realizing the magnitude of the undertaking and in order to be able to meet the situation when the time came, in 1910 San Francisco voted a bond issue of $45,000,000 for the purpose of bringing to the city a supply of pure mountain water from the high Sierras.

Much study and thought were given to the source to be tapped, and the watershed finally selected was that of the Tuolumne River which drains the northerly half of the Yosemite National Park. This project was named the Hetch Hetchy Water Supply, because the main reservoir site to be developed was the Hetch Hetchy Valley, a smaller edition of the noted Yosemite Valley. This valley lies some fifteen miles almost due north of the main valley, and is approximately four miles long and three-quarters of a mile wide, with walls rising to a height of approximately 2000 feet above the floor. At the lower end of the valley the walls close in so that the Tuolumne River flows through a deep gorge. This gorge is being closed by a dam having an initial height of 226 feet above the original stream bed, which will impound 206,000 acre-feet of water, or 67 billion gallons. This height will later be increased to 312 feet, impounding 348,500-acre feet, or 113½ billion gallons of water. Other storage reservoirs may be developed within the area drained by the Tuolumne River, Lake Eleanor being the largest of these, with an ultimate development of 168,400 acre-feet.

The Tuolumne River watershed has an area of 642 square miles, and within it are mountains reaching a height of nearly 14,000 feet. Some of the water will have to travel 180 miles before reaching San Francisco. The elevation of the country is such that it will be possible to deliver this water in San Francisco without pumping, and at an elevation which will make it possible to serve the majority of the population without resorting to pumping within the city. The ultimate development of this project will provide a continuous supply of 400,000,000 gallons of pure mountain water daily, which would be ample for a population of at least 4,000,000 people.

The undertakings necessary to get this immense job under way involved the construction of a standard gauge steam railroad from the nearest railway back into the mountains for a distance of 68 miles. The elevation to be overcome in this distance was more than 4000 feet. Sixty-pound rail, with a maximum curvature of 30 deg. and a maximum grade of 4 per cent, was employed in the work. This road involved an expenditure for roadbed alone of over $2,000,000. It is now operated as a common carrier, and in addition to carrying on the city's business, brings out from the mountain country lumber and cattle.

A headquarters camp and many construction camps have been built.

One of the first necessities was the establishment of a sawmill to make lumber for concrete forms, tunnel lining, flumes, railway ties, camp buildings and electric line poles. This plant has a capacity of 30,000 board-feet per eight-hour shift, and since it has been in operation has produced over 20 million board-feet of lumber. This plant was installed before the railway was put in, and is steam driven, using refuse for fuel. The planer and other light tools have been connected to electric drive, so that it is possible to operate them when the main sawmill is not running.

The mountainous nature of the country made it possible to readily develop hydro-electric power for construction purposes. This involved the construction of a temporary power house at Early Intake, taking water from the Cherry River, a tributary to the Tuolumne River. As is the case with all of the streams in central California, the Cherry River goes almost dry during the late fall. To supply the necessary power during this period, the reservoir site of Lake Eleanor, which through Eleanor creek is tributary to Cherry River, has been partially developed by means of a multiple arch reinforced concrete dam giving a storage capacity of 27,000 acre-feet above the original lake level.

This reservoir is filled during the spring and early summer, the heaviest run off occurring during the latter part of May. The release of stored water begins some time in August, and continues until as late as January and even into February. The released water flows down the Eleanor creek into Cherry River, which it follows to a point approximately 3½ miles above the power house, a total distance of about 15 miles from the Lake.

Here a small diversion dam diverts the water into a conduit of 200 second-feet capacity. This conduit is made up of a mile of concrete lined canal, five tunnels aggregating one mile, and 1½ miles of wooden flume. The configuration of the ground surface above the power house is such as to make it impossible to provide a forebay for regulation purposes. To give as much storage capacity as possible under the circumstances, the wooden flume which is elsewhere 7 feet 6 inches wide, and 4 feet 10 inches deep, was increased for about 2000 feet to 9 feet wide, and 9 feet 9 inches deep. At the end of this enlarged flume, which is some distance beyond the point where the penstock draws the water for the power house, a spillway is provided, allowing the safe discharge of any water which must be wasted and permitting, during the period when there is ample water, an excess of water to be sent down the canal to insure that the storage flume is brimful at all times.

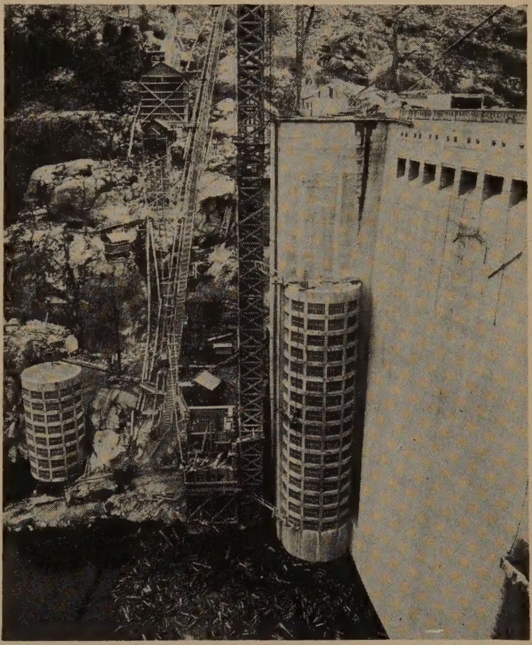


Fig. 1. Up-stream Face of O'Shaughnessy Dam showing Rack Bars covering Outlets, Inlets to Syphon Spillways and Construction Equipment including Tramway, Stairway, Concrete Pouring Tower, Concrete Mixing Plant, Cement House, Concrete Chutes, Derrick for Handling Pudding Stones and a Bank of 22,000-volt Transformers with Disconnecting Switch and Lightning Arrester

The penstock is made up of 42-inch steel pipe 530 feet long, giving a maximum head of 345½ feet on the three 1500-h.p., 720-r.p.m. Pelton-Francis turbines in the power house. Each is direct connected to a General Electric 10-pole, 2300-volt, 3-phase, 60-cycle generator of 1000 kv-a. capacity, having a direct connected 120-volt exciter. A motor-generator exciter is also installed as a spare.

The 2300-volt current generated is stepped up to 22,000 volts through a delta connected bank of 1000 kv-a. oil insulated, water cooled, outdoor type transformers set within the power house. This 22,000-volt power is carried to two oil switches operated from the main switchboard, but housed in a separate switch house from which one transmission line goes easterly toward the Hetch Hetchy Reservoir dam, and one westerly along the aqueduct, the total length of the transmission lines being more than 32 miles.

In order to reach the power house, and the aqueduct tunnel portal being driven from the same camp, a tramway had to be extended from the Hetch Hetchy Railroad down the Tuolumne River canyon wall for a length of 3800 feet, in which distance it drops 1800 feet with a maximum gradient of 89 per cent.

The transmission line, which is of triangular construction, consists of No. 4 copper wires supported from native cedar poles spaced about 225 feet apart. For a large portion of the distance the line runs through a virgin forest, necessitating the cutting of timber for a width of not less than 100 feet, in order to remove from the close proximity of the line all trees which might come down and break the line. The country is quite rough, and there are a number of ravines crossed with spans made up of stranded steel cables, in place of the ordinary copper conductors. The longest of these spans is 2200 feet.

Four hundred and forty volts was selected as the potential to be used for all power operations, while 110/220 volts was selected for lighting. The total substation capacity now connected with the power house is 7000 kilowatts, divided among the stations; the largest of these substations has a capacity of 1200 kv-a. The normal power-factor of the system varies between 40 and 75 per cent, as no small part of the load consists of motor-driven air compressors, which operate continuously, but which are equipped with an unloading device operating to stop the compression of air when a predetermined pressure has been reached, yet allowing the motor and compressor to continue running. This results in a considerable number of 100 horse-power motors always being connected to the system, but running light at intermittent periods aggregating possibly one-half of the time.

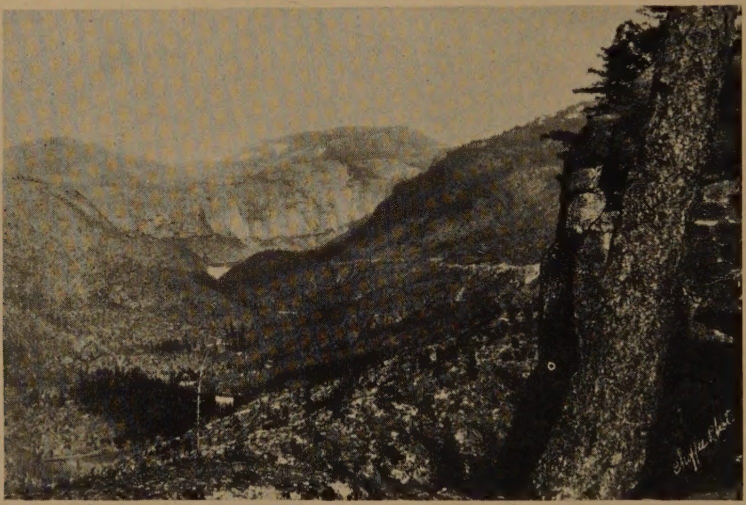


Fig. 2. Looking (8 miles) toward the Hetch Hetchy Valley from Poopenaut Pass. Dam at left center. Hetch Hetchy Railroad grade shows on right-hand canyon wall. Poopenaut Valley in foreground

At the time of the war there was a serious electric power shortage in California. The Early Intake plant was completed and placed in the city's service in May, 1918, at which time its load was very light, leaving a considerable margin of excess power. The city was ordered by the state power administrator to connect to the statewide network of transmission lines, also formed under his direction, delivering all excess power to the Sierra & San Francisco Power Company, since leased by the Pacific Gas & Electric Company.

This connection has been maintained up to the present time, supplying the city with an

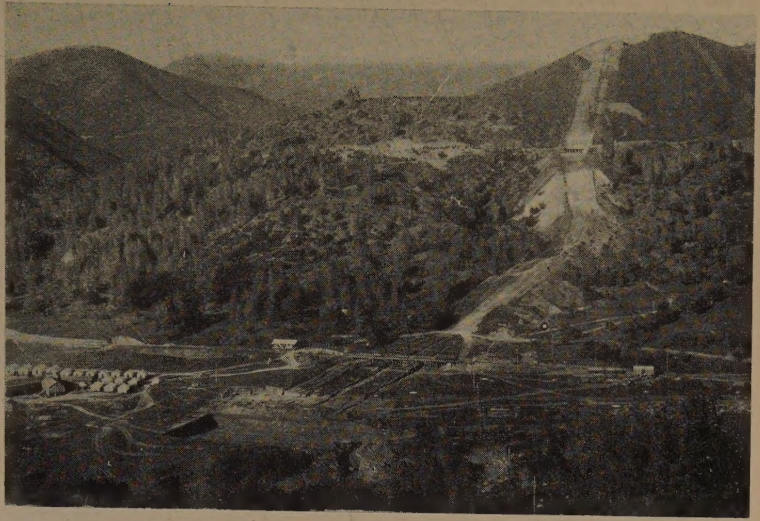


Fig. 3. Site of Moccasin Creek Power House. Excavation for building penstocks in foreground and grading for penstocks uphill. Priest reservoir is off the picture at the upper right-hand corner

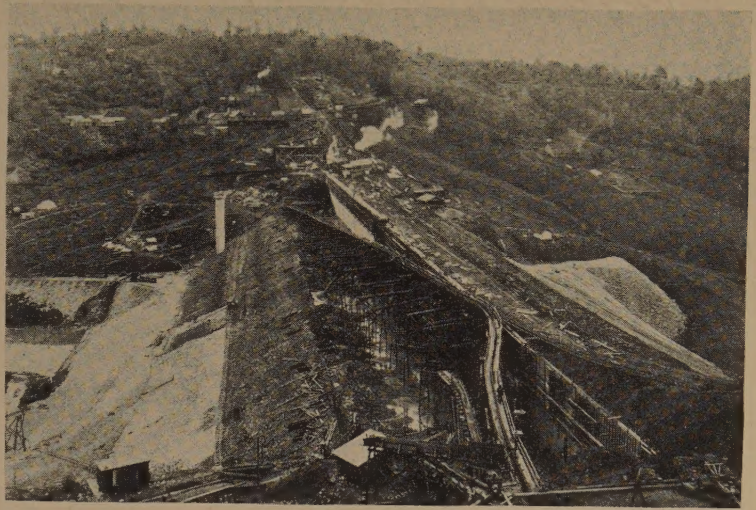


Fig. 4. Dam at Priest forming Forebay Reservoir for Moccasin Creek Power House. Rock facing on upstream face is material removed in driving the aqueduct tunnel

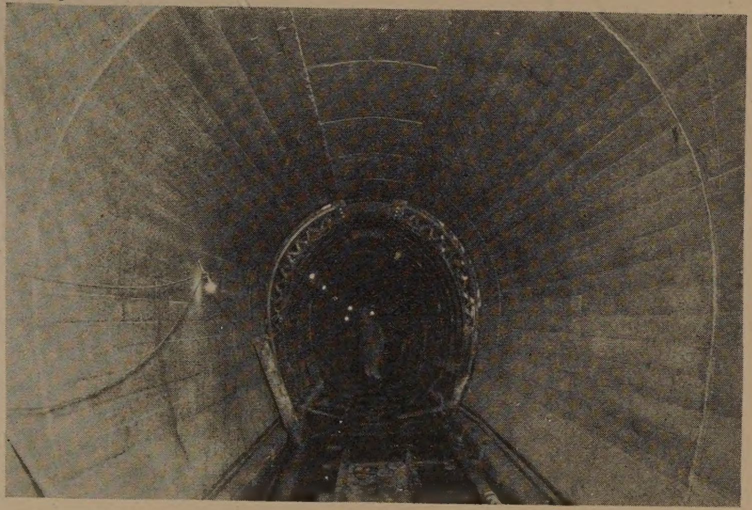


Fig. 5. A Completed Concrete Lined Section of the Hetch Hetchy Aqueduct

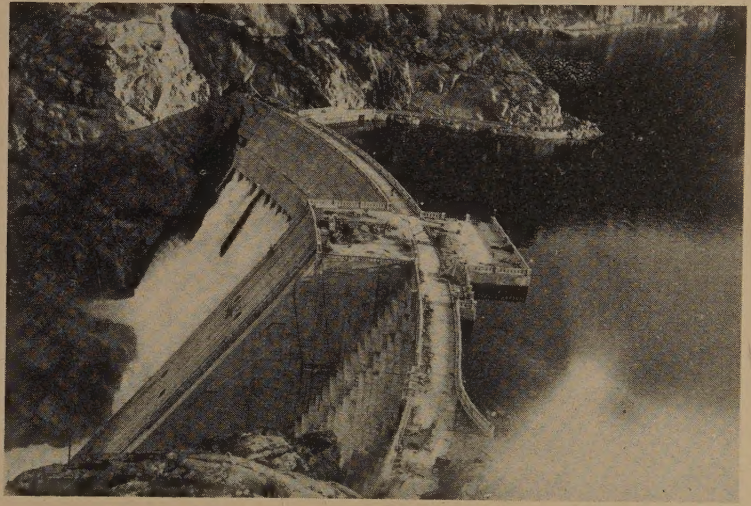


Fig. 6. A General View of the O'Shaughnessy Dam

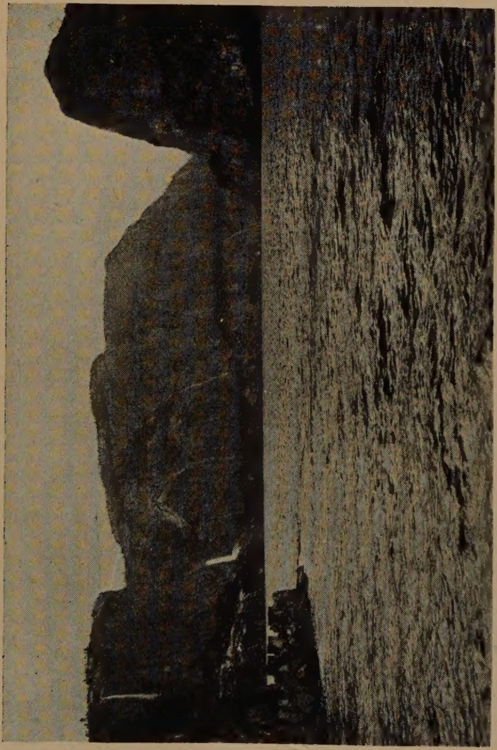


Fig. 7. Hetch Hetchy Reservoir. The perpendicular walls of the valley rise 2200 ft.

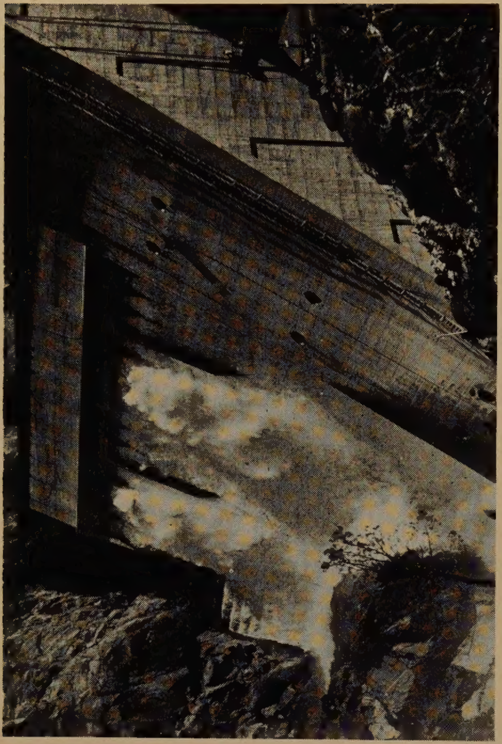


Fig. 8. O'Shaughnessy Dam showing Syphon Spillways in Operation

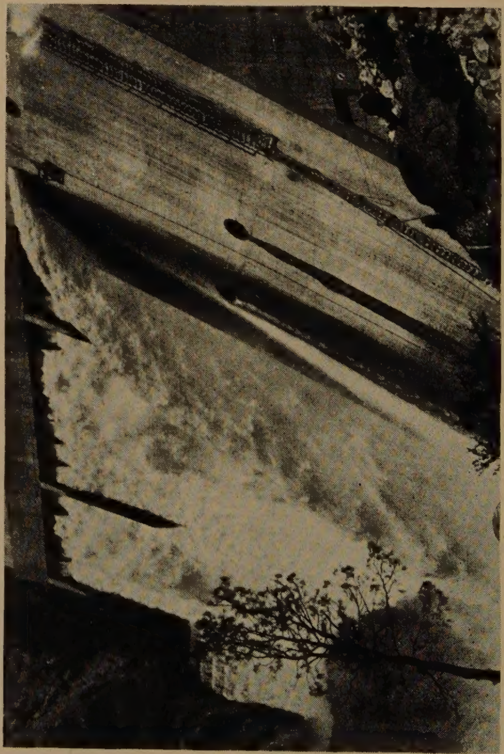


Fig. 9. O'Shaughnessy Dam showing Syphon Spillways and One Five-foot Needle Valve Discharging

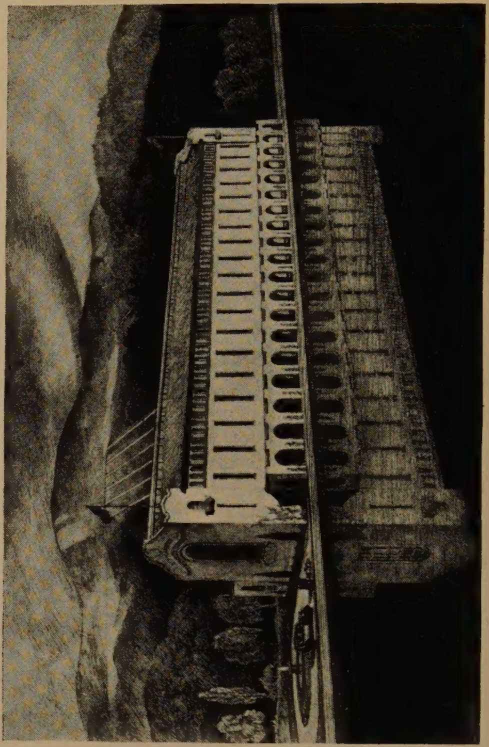


Fig. 10. Architect's Drawing of Proposed Moccasin Creek Power House Building

outlet for its excess power, assisting the Pacific Gas & Electric Company in maintaining good service on its Tuolumne circuit, and providing a standby service for both the city and the company's circuit. It has also been the means of maintaining a higher power factor than would otherwise be possible at the Early Intake plant, thus in effect increasing the capacity of the Hetch Hetchy machines. This power house, since its inception, has generated more than 90,000,000 kilowatt-hours, of which a little less than half has been delivered over this connection. Nearly 50,000,000 kilowatt-hours have already been used by the city on its construction work.

With the railroad camps, sawmill and power development completed, the main task was next in order. The present plan involves the construction of the Hetch Hetchy reservoir dam to a height of 226 feet. From this reservoir the water will flow down the Tuolumne River 12 miles to the Early Intake camp, where the temporary power house is located. Here the water will be diverted from the river into an aqueduct tunnel bored for 18.3 miles through solid granite. At the westerly end of this tunnel, the water will empty into a forebay reservoir, to be known as the Priest Reservoir, and having a capacity of 2500 acre-feet.

The maximum elevation of this reservoir's surface will be 2240 feet above sea level. The elevation at Early Intake is 2340 feet, while the elevation of the crest of the ultimate spillway of the dam at Hetch Hetchy is 3800 feet. It is thus readily seen that there is a considerable fall between the Hetch Hetchy dam and the Early Intake, where the water for the present will flow down the river. This head can later be utilized by the construction of an aqueduct parallel to the Tuolumne River, securing a power drop at a second Early Intake plant above the present construction plant having a continuous capacity of 42,000 kilowatts. The Priest Reservoir at the end of the 18-mile aqueduct now under construction is at the edge of the western extremity of the higher mountains. By constructing an outlet tunnel 13 feet in diameter from this reservoir, less than 6000 feet long, and pipe lines 5000 feet long, it will be possible to secure a static head of 1315 feet in a power house which is at the foothill level, or 926 feet above sea level. This plant is to be known as the Moccasin Creek power house. After passing through this plant, the water will flow into a tail reservoir, 920 feet elevation of water surface, which will be used to re-regulate the flow towards San Francisco, making it possible to construct the most economical size of aqueduct across the 134 miles of valley and coast range between Moccasin Creek and San Francisco. For the present, this Moccasin Creek power house, with its connected transmission lines, will complete the work on the Hetch Hetchy development, the aqueduct from the plant to San Francisco not being installed until the water is really required in San Francisco.

A short section of the aqueduct 21 miles long, however, is being built by the city at the present time between the Spring Valley Company's system in Alameda County, on the east side of San Francisco Bay, and the same Company's reservoirs on the San Francisco peninsula in San Mateo County. This link in the long aqueduct will materially extend the time which can elapse before the Hetch Hetchy water will be necessary in San Francisco by making it possible to economically transmit additional water shortly to be available from the east side of the bay into the city. This length is to be leased at an annual rental of 5 per cent of cost by the City of San Francisco to the water company until such time as it is required as a part of the Hetch Hetchy system.

This general explanation of the water situation in San Francisco, and brief description of the project as a whole, leads up to the hydro-electric development, which may be classed as a by-product of the water project. It is, however, this feature which will be of prime interest to the readers of this magazine. The Lower Cherry River development centered around the Early Intake power house will have fulfilled its mission when the construction work is completed on the mountain division east of Priest reservoir. The water now employed to turn the wheels in this plant can be diverted higher up, and brought to the Tuolumne River at a point not more than two miles above the present plant, in such a manner as to produce a static head of close to 2000 feet, generating 24,000 kilowatts in a plant to be known as North Mountain.

Neither the permanent Early Intake nor the North Mountain plant is to be undertaken at the present time. The Moccasin Creek plant below Priest Reservoir is, however, now in process of construction, and will be unique in a way as neither the North Mountain nor the Early Intake plant will be so situated as to permit of constructing a forebay reservoir. This is due to the fact that they will be in the bottom of the Tuolumne River canyon, the sides of which rise so abruptly as to provide no place for the creation of storage capacity. As the development of electricity is a by-product, and the development of water of primary importance, the flow of water through these power houses will have to be maintained at a uniform rate throughout the 24 hours, thus contributing to the economical construction of aqueducts and other water conveying or controlling devices.

In California, as elsewhere, it is impossible to secure loads of more than 100,000 kilowatts which are sufficiently constant to utilize a uniform flow of water. It has therefore been necessary to consider the three large plants, North Mountain, future Early Intake, and Moccasin Creek as one big plant when planning to care for load regulation. The water available in the aqueduct—620 second-feet—will not develop continuously more than 52,500 kilowatts at Moccasin Creek. However, through the utilization of the fine forebay and tail bay capacity available at that site, it will be possible to operate this plant at a load factor of less than 50 per cent. This feature will make Moccasin Creek power house the plant which will have to take the swings of all three plants incident to the changes in load over the 24 hours. At the present time four units of 20,000 kv-a. capacity are being installed, three of these units at 87½ per cent power-factor running continuously will use all of the water which is available. The fourth unit will be needed to meet the daily load fluctuations incident to operating on the Central California load factor. When the other two plants are constructed, it will be necessary to install two more similar units in the Moccasin Creek plant, even though no additional water is developed, permitting of increasing the daily kilowatt-hours output beyond that of three units at 100 per cent load factor. Then at the hours of minimum demand, none of the units at this plant will be required, yet over the daily peak it will be necessary to operate all six units in order to secure a load factor of 70 per cent for the three plants. This method of running the water through the power house is what entails the construction of a reservoir below the power house to regulate the flow on towards San Francisco, so as to secure the most economical form of aqueduct.

Contracts have already been awarded to the Pelton Water Wheel Company for furnishing four double overhung, 25,000 horse-power impulse waterwheels. These will have an efficiency of 83½ per cent when outputting 25,000 horse power, 84 per cent at 20,000 horse power, and 82 per cent at 12,500 horse power. These figures are based on an effective head of 1250 feet with a speed of 257 r.p.m. The waterwheel elements of each unit will weigh between 350,000 and 400,000 pounds. A contract has been awarded to the General Electric Company to furnish the four 20,000 kv-a. generators to go with these waterwheels. These units, operating at 11,000 volts, will weigh 250,000 pounds, and have a moment of inertia of 3,000,000 foot-pounds. The efficiency of these generators will be as follows: At 87½ per cent power-factor and with 17,500 kilowatts output, 96.8 per cent, and with 13,125 kilowatts output 96.1 per cent. As a part of these units there will be installed a direct connected exciter of 140 kilowatts capacity, overhung on the waterwheel shaft and extending beyond the waterwheel. This is a new development, and as far as is known, is the first instance in which a direct connected exciter has been attached to a large double overhung waterwheel unit.

In connection with this article it is interesting to note the heights of the principal dams in the world. They are as follows:

	Feet
Arrowrock, Idaho	349
O'Shaughnessy Dam, California	341
Tieton, Washington	330
Shoshone, Wyoming	329
Kensico, New York	307
Elephant Butte, New Mexico	306
Croton, New York	297
Roosevelt, Arizona	280
Ashokan, New York	252
Burrinjuck, Australia	240
Assouan Dam, Nile, Egypt	131

When the O'Shaughnessy Dam is completed with an addition of 85 feet the San Francisco structure will, by a large margin, be the tallest dam in the world.

Joseph Henry

By E. W. Rice, Jr.

Honorary Chairman of the Board, General Electric Company

We are very pleased to be able to publish an address on Joseph Henry by Mr. E. W. Rice, Jr. Mr. Rice broadcast this description of the work of America's famous scientist over WGY on the evening of December 17, 1923, which was the 126th anniversary of Henry's birth.—Editor.

It is a rare privilege to be able to say a few words tonight as a tribute to the memory of Joseph Henry, scientist, physicist and scientific administrator, a man whose memory all the world delights to honor.

Joseph Henry was born in Albany, December 17, 1797, and died in Washington, May 13, 1878.

He became Professor of Mathematics in the Albany Academy at Albany, N. Y., in 1826, Professor of Natural Philosophy of the College of New Jersey at Princeton in 1832, and was the first Secretary and Director of the Smithsonian Institution in 1846.

He made many original contributions to science in electricity, electromagnetism, meteorology, capillarity, acoustics and other branches of physics, and devoted the last 32 years of his life to making the Smithsonian Institution an efficient instrument for "the increase and diffusion of knowledge among men."

Joseph Henry was of Scotch descent. His father, of whom little is known, died when Joseph was about nine years old. His mother was a woman of refinement, "delicate in form and feature, very beautiful, and deeply devotional." At the age of seven he went to live with his maternal grandmother at Galway, near the city of Schenectady, where he attended the country school. At ten, he was placed in a country store where he worked for five years. His employer very kindly permitted him to attend school in the afternoons. He was said to be "a handsome, slender lad, of delicate complexion, vivacious manners, and a great favorite." He was fond of reading, especially books of fiction, and with a highly imaginative mind, loved to amuse the young villagers by relating to them the stories which he had read.

When about 14 years old, he served a brief apprenticeship to a silversmith in Albany. While the work was not congenial, it was of value in giving him an opportunity to acquire the manual dexterity so useful to him in after life.

His interest in science was early aroused by finding a small book which a Scotchman had left upon his mother's table, entitled, "Lectures on Experimental Philosophy, Astronomy and Chemistry," which began by asking such questions as why a stone thrown into the air stops at a certain distance and then returns; why smoke or flame always mounts upwards; what is reflection of light? The influence of this book upon Professor Henry's life is indicated by the following entry made in his own handwriting: "This book, although by no means a profound work, has, under Providence, exerted a remarkable influence upon my life. It accidentally fell into my hands when I was about 16 years old and was the first book I ever read with attention. It opened to me a new world of thought and enjoyment, invested things before almost unnoticed with the highest interest, fixed my mind on the study of nature, and caused me to resolve at the time of reading it that I would immediately commence to devote my life to the acquisition of knowledge."

This resolution proved no light undertaking. His mother's means were too limited to permit of his constant attendance at school. He began by taking evening lessons from two of the professors in the Albany Academy, making a special study of geometry and mechanics. He learned grammar from a traveling teacher, and having mastered this subject, traveled about the country and earned money to enter the Albany Academy. By teaching at intervals, and practicing strict economy, he was able to earn enough to complete his studies at the Academy, from which he graduated at the age of 18. He then obtained a position as private tutor, which required only his morning hours, and devoted his afternoons to further mathematical and physical studies.

He became an assistant to Dr. Beck, Professor of Chemistry at the Albany Academy, and immediately showed his ability as an experimentalist. He prosecuted his studies with such ardor that his health failed and he was forced to abandon his position. Fortunately he found an opportunity to join a surveying expedition in New York State. In this outdoor work his health and vigor were completely restored.

Upon his return in 1826, he was elected Professor of Mathematics in the Albany

Academy and at once began his career in physical research.

Sturgeon of England made an electromagnet in 1825. It consisted of a small iron bar bent into a horseshoe form, having about 18 turns of copper wire wound loosely around it. This was the first electromagnet, and a most interesting scientific instrument.

Henry in 1828 exhibited before the Albany Institute an electromagnet closely wound with silk covered copper wire. By thus insulating the conducting wire, instead of the iron bar, he was enabled to employ a compact coil containing a much larger number of turns, and giving a lifting power much greater than Sturgeon's magnet.

This was the first time that the individual copper wires were insulated with a covering of silk or cotton thread. He used this new product, insulated wire, to make a magnetic "spool" or "bobbin" consisting of series of coils many layers deep. This method has since been used in every application of the electromagnet.

In March, 1829, Henry exhibited a larger magnet constructed in the same manner, and shortly thereafter produced electromagnets capable of lifting several hundred pounds. Henry thus converted the scientific instrument of Sturgeon into the powerful and practical implement of today. No fundamental advance has been made over the electromagnet given us by Henry nearly 100 years ago.

Sturgeon said of Henry's electromagnet: "Henry has been enabled to produce a magnetic force which totally eclipses every other in the annals of magnetism, and no parallel is to be found since the miraculous suspension of the celebrated oriental impostor in his iron coffin."

Ampere in 1820 had made the suggestion that "by sending the galvanic current through long wires connecting two distant stations, the deflections of enclosed magnetic needles would constitute very simple and efficient signals for an instantaneous telegraph." But in 1825 Barlow, an eminent English physicist, tested Ampere's idea and found that the introduction of only 200 feet of wire made such a reduction in the effect as to convince him of the impracticability of the scheme.

Henry attacked this problem in 1830-31, and found that with his "intensity magnet" supplied with current from an "intensity battery," he could produce an undiminished effect with even 1000 feet of wire interposed. He then developed in a thoroughly scientific manner the relation of what he called the "intensity magnet" to the "intensity battery," and the "quantity magnet" to the "quantity battery." The intensity magnet was one of many turns of wire, and the intensity battery one with many cells connected in series.

He thus made the electromagnet capable of use in transmitting power to great distances, and was the first to magnetize a piece of iron at a distance and to thereby demonstrate the possibility of the use of the electromagnet for telegraphy.

He was the first to use the magnet as a signaling device, sounding a bell by his magnet through a wire over a thousand feet in length. He describes this as follows:

Sometime during 1831, "I arranged around one of the upper rooms of the Albany Academy a wire of more than a mile in length through which I was enabled to make signals by sounding a bell. The mechanical arrangement for effecting this object was simply a steel bar, permanently magnetized, of about ten inches in length, supported on a pivot and placed with its north end between the two arms of a horseshoe magnet. When the latter was excited by the current, the end of the bar thus placed was attracted by one arm of the horseshoe and repelled by the other, and was thus caused to move in a horizontal plane and its further end to strike a bell suitably adjusted." This was the first sounding electromagnetic telegraph.

All this was accomplished between 1828 and 1831, many years before the telegraph was introduced by Morse in America, and at a time when Barlow in England had declared that there could be no electric telegraph to a long distance, and Wheatstone, the originator of the needle telegraph system established in England, said as late as 1837, speaking of the electromagnet: "It would not act and could not act as a telegraph because sufficient attractive power could not be imparted to an electromagnet interposed in a long circuit." It was evident that Wheatstone was not informed in 1837 of what Henry had demonstrated in 1831.

Henry was therefore the father of the useful electromagnet, the foundation of the electrical industry. Henry's magnet was used in the discovery of diamagnetism, the effect of magnetism on light, magneto electricity, and other astounding revelations of the laws of nature.

Every electric dynamo or motor uses the electromagnet in the form in which it was left by Henry in 1829; in fact, practically every piece of electrical apparatus depends wholly or in part upon Henry's magnet for its operation.

In 1832 Henry discovered the induction of an electric current upon itself in a long wire, which we now called "self-induction," and soon thereafter made the greatest discovery of the age: that electricity could be produced from magnetism.

It is a remarkable coincidence that this great discovery, which Henry stated would certainly form "a new era in the history of electricity and magnetism" should have been made independently by two men, Joseph Henry in America and Michael Faraday in England at about the same time. Telegraphic communication did not exist between England and America at that time and months, sometimes years, elapsed before scientific discoveries in one country were made known in the other. Therefore, it does not detract in any degree from Henry's credit that Faraday made his discovery a few months earlier.

Professor J. A. Fleming, of London, writing in 1892, states that Henry's claim to be an independent discoverer of the fundamental effect of electromagnetic induction "is not now disputed," and goes on to say that "in the July number of Silliman's *Journal of Science* for 1832, Joseph Henry, then a young teacher in the Albany Academy, gave an account of the manner in which he had independently, and before receiving an account of Faraday's work (performed in the previous autumn), elicited from his own great electromagnet an induced current by wrapping around the soft iron armature certain coils of insulated wire." Upon making and breaking the circuit of his electromagnet, a current of electricity was induced in the coils surrounding the armature. "This simple experiment," Fleming says, "disclosed for the first time in history a method of obtaining from magnetism a current of electricity."

Every electric generator which converts the mechanical power of steam, of gas, or of falling water into electricity, is dependent upon this discovery, as also is every electric motor from the tiny fan motor which cools us in summer to the motors which run our trolley cars and city subways or pull our great trains over the mountains.

This discovery, as well as that other contribution of Henry's which taught us how to change high tension current into low tension current, or the converse, low tension current into high tension, is utilized in every electric transformer.

It is especially interesting on this occasion to remember that many of Henry's discoveries and inventions, and much of the electrical apparatus which he developed find their application in devices used in wireless telegraphy and telephony.

Our wireless friends will be particularly interested to learn that he showed that the current induced in the secondary of two of his coils could be varied or regulated by changing the relation in space of the coils. Upon this is founded the "variometer" now used in nearly all radio applications.

But this was not all. He even discovered the oscillatory nature of the discharge of a Leyden jar; the screening effect of a solid metal sheet interposed between the primary and secondary coils, and also showed how this screening effect could be controlled and even eliminated.

After removing to Princeton, Henry continued his researches and made a long series of brilliant discoveries with his so-called "flat spirals," determining the principles upon which the electric transformer of today is constructed.

It is surprising to find that he also pointed out that "closed currents" may circulate in the iron itself which would interfere with the intensity of the induction in the surrounding wire, and he thereby explained the cause of the improvement effected by substituting a bundle of iron wires for solid iron when such iron is subjected to variable magnetic induction.

He also experimented with so-called ordinary or frictional electricity obtained from a charged Leyden jar and demonstrated that the discharge of a Leyden jar would produce "electricity in motion" and magnetic effects similar to those produced by the current from his galvanic batteries. He thus established the identity of electricity in motion, or "electric current," whatever the source from which it was produced. This was an achievement comparable with that of Franklin, who by his famous kite experiment discovered the identity of lightning and electricity.

He also studied the effect of lightning induction on telegraph wires, and suggested that its destructive effects could be diminished by erecting on the supporting poles a grounded metallic wire in close proximity to, but not in contact with the telegraph wire.

He invented the so-called electric relay, by which a relatively feeble current operated an electromagnet, which in turn controlled the local circuit of a more powerful magnet. This invention is not only used in telegraphy, but also most extensively in other electric engineering—for instance, in the operation of switches and for signals at a distance; in the trolley car and the electric elevator; in fact, the entire modern method of electric control known as "remote control" is but a natural extension of Henry's relay system.

He showed that the discharge of a Leyden jar traveled largely over the surface of a conductor, rather than through its interior, and that Ohm's law did not exactly apply in this case.

Practically all of Henry's remarkable researches and original contributions to science were made while he was a professor at Albany Academy and at Princeton College.

In 1846 he was called to accept the position of Secretary of the Smithsonian Institution at Washington, an Institution which, it is well known, was formed to give effect to the legacy of James Smithson, of England, who in a will executed in 1828 devoted his patrimony to found at Washington an establishment for "the increase and diffusion of knowledge among men." Whatever success this Institution has achieved is based upon the practical wisdom, perseverance and genius of Henry who devoted the remainder of his life to its upbuilding.

He was the first to apply the telegraph, which was then in its infancy, to meteorological work, and to make weather forecasts embracing a continent.

During the last 25 years of his life he was a member of the American Lighthouse Board, and for many years, until his death, its presiding officer.

It was due to his work that one of the most serviceable systems of fog signals was produced.

While his reputation will rest largely upon his electrical work, he made notable researches in other scientific fields, for example: he studied sun spots by a thermo telescope of his own invention, and discovered that these were cooler than the rest of the sun's surface. He made notable discoveries in the field of acoustics and examined into the obscure phenomena of phosphorescence. He investigated the cohesion of liquids and demonstrated the fallacy of existing popular views by showing that the cohesion in liquids was actually of the same order as that in solids.

In 1837 Henry first visited Europe and became personally acquainted with its principal men of science, among them the great Faraday. It is a great satisfaction to learn that these two great men, Faraday and Henry, not only had no disputes as to their contributions to science, but such records as have been left clearly show that each held the other in the highest esteem and had nothing but mutual regard and kindly feeling one toward the other. In fact, Faraday often spoke of Henry in terms of hearty regard and admiration and Henry apparently loved to dwell on the happy hours that he spent in Faraday's society upon the occasion of his visit to London. These two men were much alike in their simplicity of character, genuineness, freedom from affectation and loving devotion to scientific research.

It is not for us to define Henry's position as a scientific man. This has been done by others who were better fitted to the task. Sir David Brewster said, "The mantle of Franklin has fallen upon the shoulders of Henry." It is certain that his name will ever be treasured with those other intellectual giants whose researches made possible the electrical industry—Franklin, Oersted, Ampere, Ohm, Volta, Galvani, Helmholtz, Davy, Faraday, Maxwell and Kelvin—to mention but a few of those who have passed away.

It has become the custom to confer the names of eminent discoverers upon electrical units. For example: the name of Volta, who invented the Voltaic pile, the first electric battery, is to be found in the "volt," the common unit of electric pressure; the name of "ampere" has been given to the unit rate of electric flow after Ampere who made numerous discoveries in electricity and magnetism; the name "ohm" to the unit of electrical resistance, after Ohm who explained the relation between electric pressure, current, and resistance; and the name of "farad" to another of our units in honor of the great Faraday. So it is quite fitting that we find the name of "Henry" given to the unit of electric inductive effect in honor of our Joseph Henry, and it is pleasant to remember that this name was first given to the unit at the International Electrical Congress held in Chicago in 1893, and was unanimously adopted by the delegates representing not only this, but all other important foreign countries.

The fame and influence of great men are not to be limited by political boundaries, but we may be permitted to take special satisfaction in the fact that Henry was born in America, in the city of Albany, and honored Schenectady by taking as his wife Harriet L. Alexander of this city. It must also add to the interest of this occasion to recall that it was in Albany and close to this place that Henry started on his great career in the acquisition of knowledge and its diffusion for the benefit of his and future generations to the end of time.

The character and quality of a nation's civilization may be judged by the things which it prizes, and the men whom it honors. Judged by this standard, the American people are to be congratulated upon the selection of the man to whose memory we are tonight paying our grateful tribute.

* * * * *

I will now ring by hand the identical bell which Henry rang by his electromagnet at Albany in 1831, so that all who are "listening in" may hear the sound of this historic bell. When first rung by Henry, it could only be heard by those in its immediate neighborhood, within reach of the original air waves. Now, while I am ringing it, it may be heard thousands of miles away, even half way round the world, and it is a remarkable fact that even those who are most distant are actually hearing the sound of the bell before it is heard by many in this room.

The discoveries and inventions which make it possible for you to hear the sound of this tiny bell over such vast distances are the result of nearly 100 years of scientific progress with which will ever be imperishably associated the name of Joseph Henry.

A Corner of the Main Studio of WGY

The 65,000-kv-a. Vertical Waterwheel Generators for the Niagara Falls Power Company

M. C. Olson and E. B. Plenge

Alternating-current Engineering Department, General Electric Company

The largest electric generator in the world was placed in commercial operation last December at the Niagara Falls Power Company's plant just below the Falls on the American side. This machine measures 31 ft. outside diameter and weighs 750 tons. To ship the generator to its destination required 35 cars. This hydro-electric unit draws no additional water from the river, however, for its higher head and efficiency enable it to generate twice the electrical energy from the same quantity of water as was formerly used to drive seven 5000-h.p. units. Its operation, combined with that of two similar machines now being built, will therefore furnish an additional 100,000 h.p. without diverting more water from the Falls. Many of the unusual design features of this first 65,000-kv-a. machine are described in the following article.—Editor.

Within the last few years tremendous strides have been made in the building of large waterwheel-driven units. This increase in development of our waterpower resources is due to the increasing price of fuel, transportation and labor, and to the limited supply of our fuel reserves.

Fig. 1 shows the trend in capacity of the large alternating-current waterwheel-driven generators built by the General Electric Company during the last twenty years. It will be noticed that in 1909 the largest waterwheel-driven unit on order was 15,000 kv-a., in 1918 it was 32,500 kv-a., in 1920 it was 40,000 kv-a., and in 1922 it was 65,000 kv-a. Thus, it can be seen that the capacity of such generating units has doubled during the last four years. The dotted curve, however, shows the general trend in capacities that might have been expected, but the new Niagara generators for adequate reasons were made considerably larger in size.

The efficiency of the combined unit, waterwheel and generator, has made great gains in the last decade. Especially important is this in the 65,000-kv-a. generators that are described in this article, as the allowable amount of water that can be used by the Niagara Falls Power Co. is limited by treaty between the United States and Canada. It is estimated that approximately 4,000,000 h.p. could be developed at Niagara Falls without affecting the scenic beauty of the Falls. Of this amount, about one-sixth has been developed.

This article describes some of the design features involved in building two of these 65,000-kv-a. vertical generators, the largest waterwheel-driven machines in the world. In every detail special precautions were taken to secure both electrical and mechanical reliability.

These units are driven by 70,000-h.p. hydraulic turbines under an effective head of 213.5 ft. The arrangement of the generator, waterwheel, and the 21 by 14-ft. Johnson valve is shown in the cover illustration of this issue of the Review. The turbines and Johnson valves are furnished by the I. P. Morris Department of the Wm. Cramp & Sons Ship & Engine Building Co.

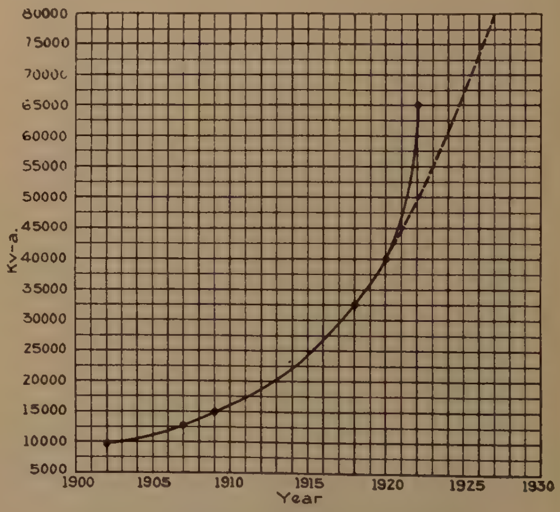


Fig. 1. Curve showing Trend in Capacity of Large Hydro-electric Units

The generators are rated 65,000 kv-a., 52,000 kw., 0.8 p-f., 12,000 volts, 25 cycles, 28 poles, and 107 r.p.m., and have a guaranteed efficiency of 98.1 per cent at 65,000 kv-a., 1.0 p-f. and 97.8 per cent at 0.9 p-f. and 97.5 per cent at 0.8 p-f.

The temperature guarantees are as follows: At 65,000 kv-a., 0.8 p-f. continuous operation, the temperature rise on the stator will not exceed 50 deg. C. by thermometer and 60 deg. C. rise by imbedded resistance temperature detectors. The guarantee on the rotor is 55 deg. C. by resistance. These generators will operate at 5 per cent in excess of the rated output of 65,000 kv-a. at any power-factor not lower than 0.8 and at any voltage between 12,000 and 13,200 without exceeding the safe operating temperature of insulation, provided the ambient temperature does not exceed 35 deg. C.

There are 24 resistance temperature detectors in the stator for indicating the temperature of the armature winding. Some of these are located between the coils in the slot and some are located at the bottom of the slot.

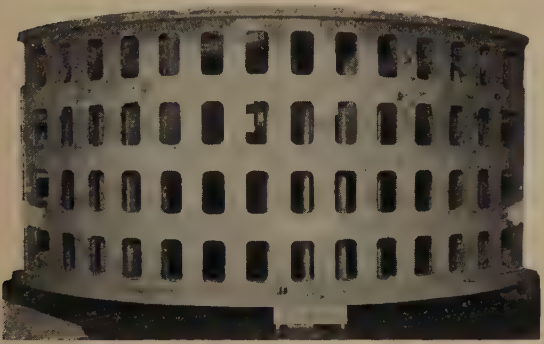


Fig. 2. Outside View of a Quarter Section of the Stator Frame

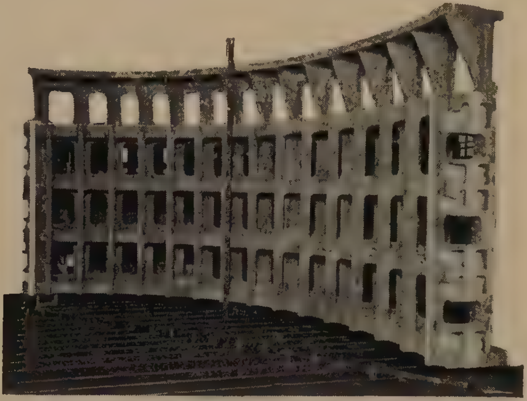


Fig. 3. Inside View of a Quarter Section of the Stator Frame

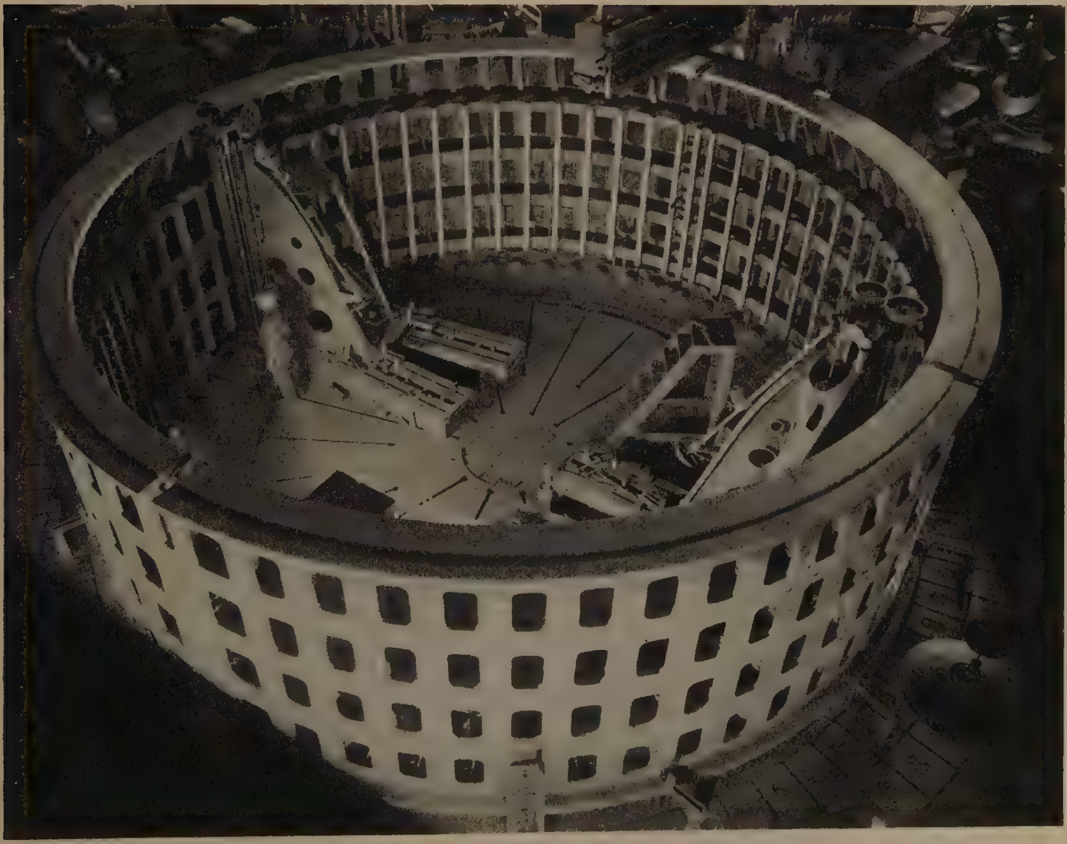


Fig. 4. Assembled Stator Frame in Process of Machining

Excitation Generator

A novel feature in the design of this unit is the mounting of a 650-kv-a., 3-phase, 2200-volt excitation generator between the rotor spider and upper bearing bracket of the large machine. This 650-kv-a. generator supplies current for the motor-generator sets that furnish the direct-current excitation for the 65,000-kv-a. machine. It will also furnish current for operating blowers and pumps.

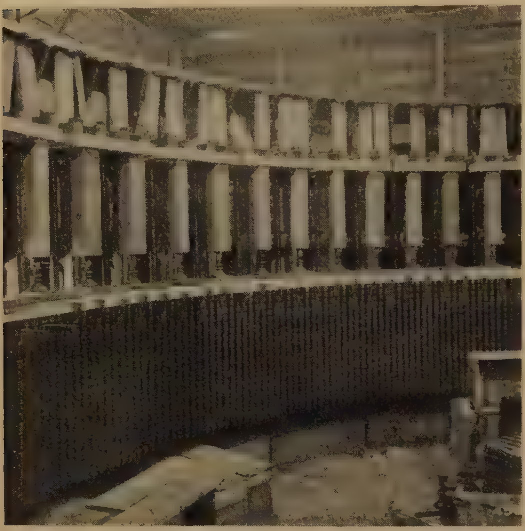


Fig. 5. Stator Punchings being Assembled in Frame

Stator

Figs. 2 and 3 show the general construction of the outside and inside of one-quarter of the stator frame before machining and Fig. 4 the assembled stator as it looked in the process of machining at the factory. Each section has a gross weight of approximately 42,600 lb. The outside diameter of the stator is 30 ft. 4 in. and the height is 10 ft.

The stator punchings are held in place by keys attached to the stator ribs, and are firmly clamped between cast-steel flanges at top and bottom of the stator by means of 120 steel studs, 2½ in. in diameter.

On account of the great weight of this machine, the punchings were assembled at the power station. Fig. 5 shows the method of assembling the punchings and the jacks used for pressing at very frequent intervals so as to obtain a tight core, the length of which in this case is 7½ ft.

The stator frame is supported on a continuous cast-iron base ring which weighs approximately 53,000 lb. and is shown in Fig. 6, being machined by two revolving planers. This base is partly imbedded in concrete at the power station. In it there are 24 bolts for centering the stator frame and 24 steel holding-down bolts of 2½-in. diameter. In addition there are twenty-four 1½-in. diameter radial dowels to prevent any movement between stator and base under the most severe conditions of short circuit.

Armature Winding

The armature coils in this machine are each 10 ft. 7 in. long and approximately 25 in. in width. Each coil with its insulation weighs approximately 200 lb. The insulation consists of mica, each turn also being insulated

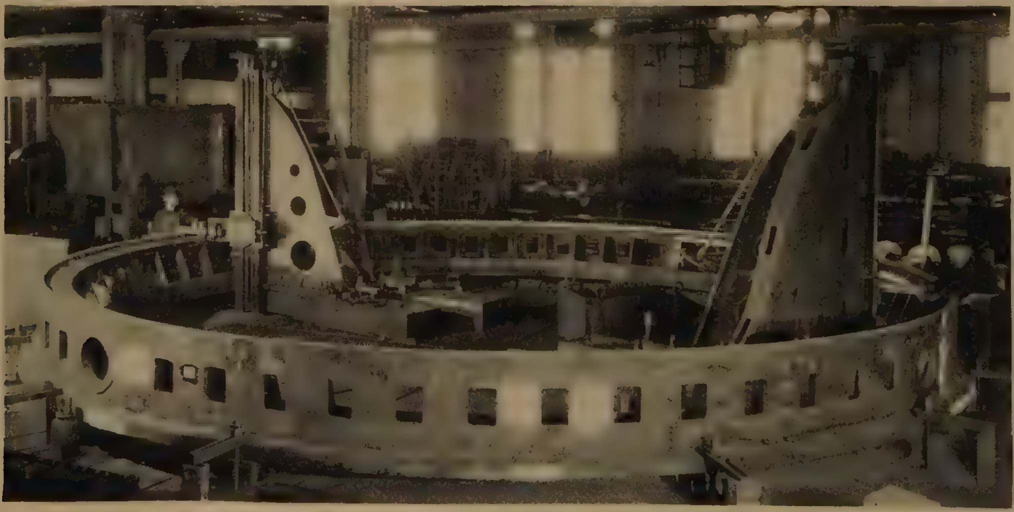


Fig. 6. Base being Machined on Large Boring Mill

with mica tape. Fig. 7 shows one of the insulated coils. At the ends, top and bottom, the armature coils are laced to two steel supporting bands to prevent any distortion of the windings due to short circuits.

Fig. 8 shows the coils being assembled in the stator at the power station. The armature connections are all made at the top of the machine.

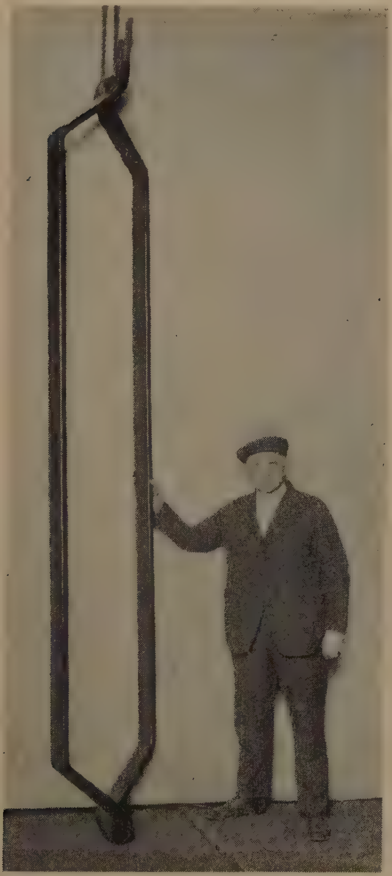


Fig. 7. Armature Coil approximately 10 ft. 7 in. long and 2 ft. 1 in. wide

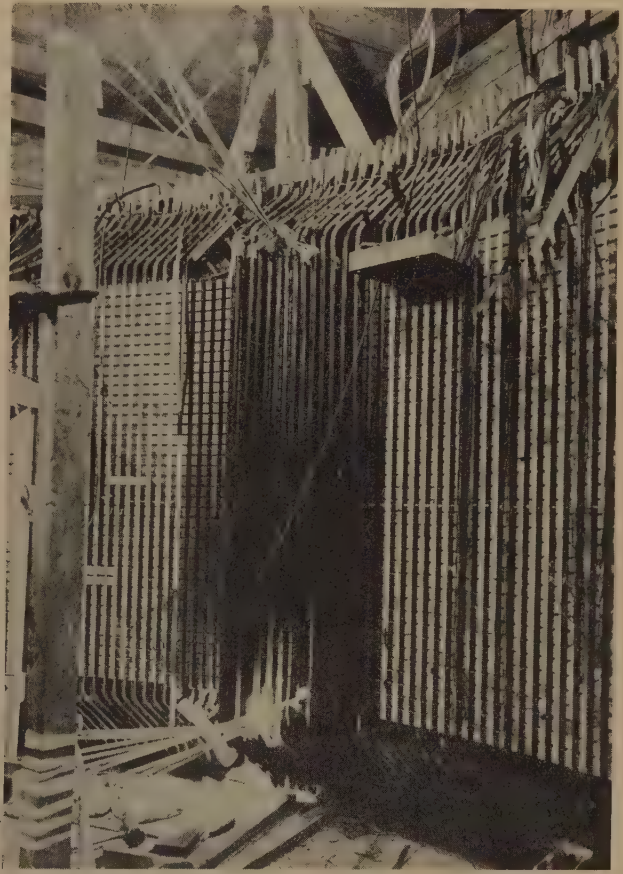


Fig. 8. Armature Coils being Assembled in Core

Upper Bearing Bracket

The upper bearing bracket is made very similar to the standard design for machines of large diameter. This structure consists of a cast-steel central hub 10 ft. in diameter and 6 ft. 4½ in. high, having a weight of 42,000 lb. To this are bolted ten cast steel arms having heavy central ribs, each arm weighing 7800 lb. These arms have a projection at the upper end which fit in a rabbet in the central hub. When the structure is finally bolted together and machined, dowels are put in to relocate the arms in their proper position when assembling at the destination. In order to avoid the possibility of oil leakage through porous spots which might occur in the bearing bracket casting, a one-inch thick steel plate is provided to form the bottom of the thrust bearing oil well. The bolts for attaching the plate to the bracket are located outside the housing so that there can be no leakage around the bolts. Steel lugs are welded to the under side of the plate at the points where the dowel pins for the thrust bearing pass through it. The assembled bracket has a total weight of approximately 120,000 lb.

This bracket must support the weight of the generator rotor, excitation generator, waterwheel, and hydraulic thrust; the total weight of which amounts to approximately 1,143,000 lb.

Fig. 9 shows the thrust bearing housing and brush rigging, and Fig. 11 the collector rings for the fields of the main generator and the excitation generator. These parts are designed so as to be readily accessible and to be convenient to dismantle. The outside diameter of the collector rings is 38 in. The excitation current is carried to the main generator and exciter generator field by busbars through a hole in the shaft. The support for the collector rings is bolted to the end of the generator shaft. At the top of the generator is mounted a speed-limit switch.

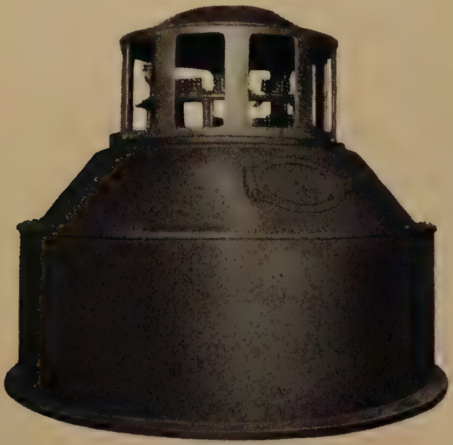


Fig. 9. Thrust Bearing Housing and Collector Ring Cover

Rotor

On account of the unusual size of this rotor, the field spider is made up of five separate wheels, each wheel being split. The two halves of each wheel are bolted together at the hub by means of twelve 3½-in. diameter nickel-steel studs which are heated when put in place.

The rims are joined together by special nickel-steel links which also are heated when assembled at the destination. Fig. 10 shows one of the assembled wheels. The ten sections have a total weight of 380,000 lb.

With each section of casting, there was attached a test coupon for determining the character of the material entering into it. Tests were also made from test pieces from

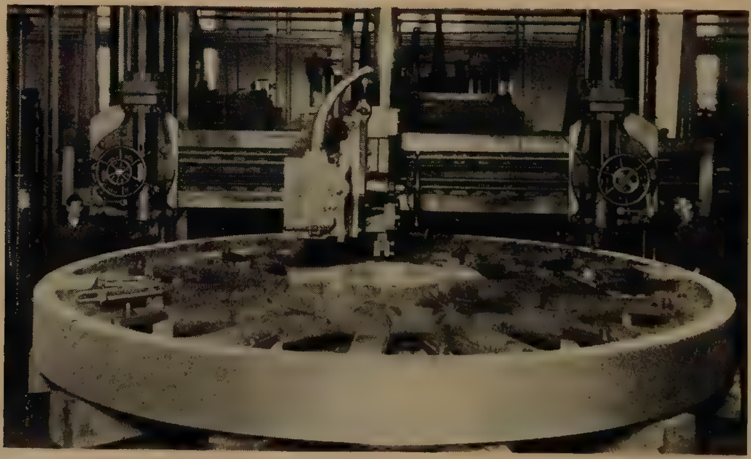


Fig. 10. Rotor Spider is Made up of Five of These Wheels

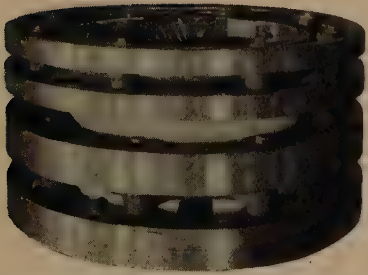


Fig. 11. Collector Rings for Main and Excitation Generators

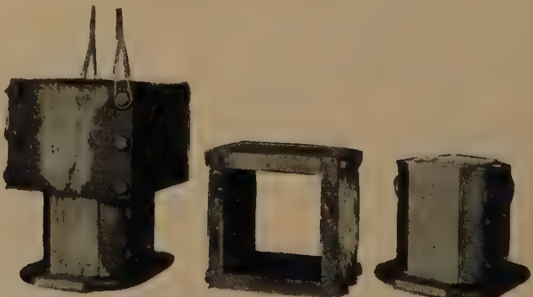


Fig. 12. Pole Pieces and Weights used in Making the Overspeed Test

the nickel steel links that were used for joining the field rim.

The rotor is designed for an overspeed of two times normal. On account of the great height and weight, it was not feasible to test the completed rotor at the factory. Each wheel of the rotor, however, was given an overspeed test of two times normal for two minutes. This is a more searching test than if the whole rotor had been tested, as each wheel had to withstand by itself the proportional strain imposed upon it.

In order to duplicate the stresses in these wheels when making the overspeed test, sections of pole punchings with end plates were bolted together as shown in Fig. 12. Around each pole were bolted steel plates to take the place of the field copper to obtain the same stress. Fig. 13 shows the rotor completely assembled in the power station.

The shaft of this generator has a diameter of 34 in. at the bore of the field spider and the diameter of the forged coupling is 59 in. The coupling bolts that connect the generator shaft to the waterwheel shaft consist of eighteen 4½-in. diameter bolts. The holes for these are reamed to exact size at the destination.

Pole Punchings

Each pole is attached to the rotor rim by means of twenty 2¼-in. diameter nickel-steel bolts. The pole punchings are clamped together by means of through bolts.

With this large capacity and 250-volt excitation, it was necessary to have a field winding each turn of which is 0.43 in. thick. The approximate width of each coil is 21 in., height 16 in. and its length approximately 8 ft. 4 in. A field coil is shown in Fig. 15. To hold this immense weight of copper in place at overspeed, a coil bracket is placed

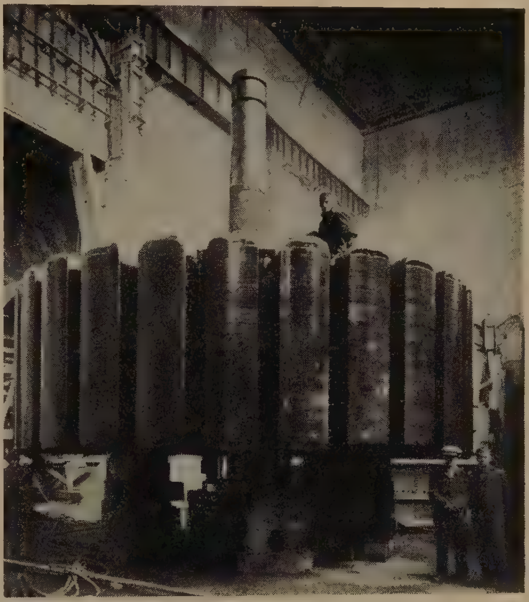


Fig. 13. Rotor Completely Assembled

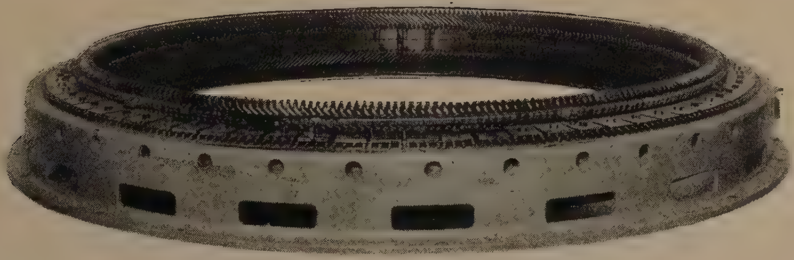


Fig. 14. Stator of 650-kv-a. Excitation Generator

Fig. 15. Field Coil Approximately 8 ft. 4 in. long, 1 ft. 9 in wide and 1 ft. 4 in. high

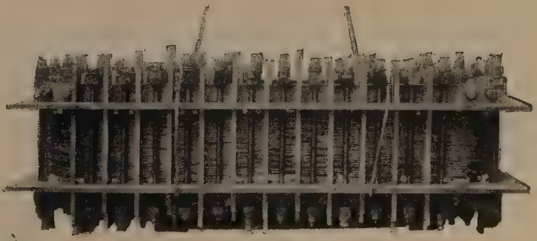


Fig. 16. Device used for Pressing Field Coils to Size

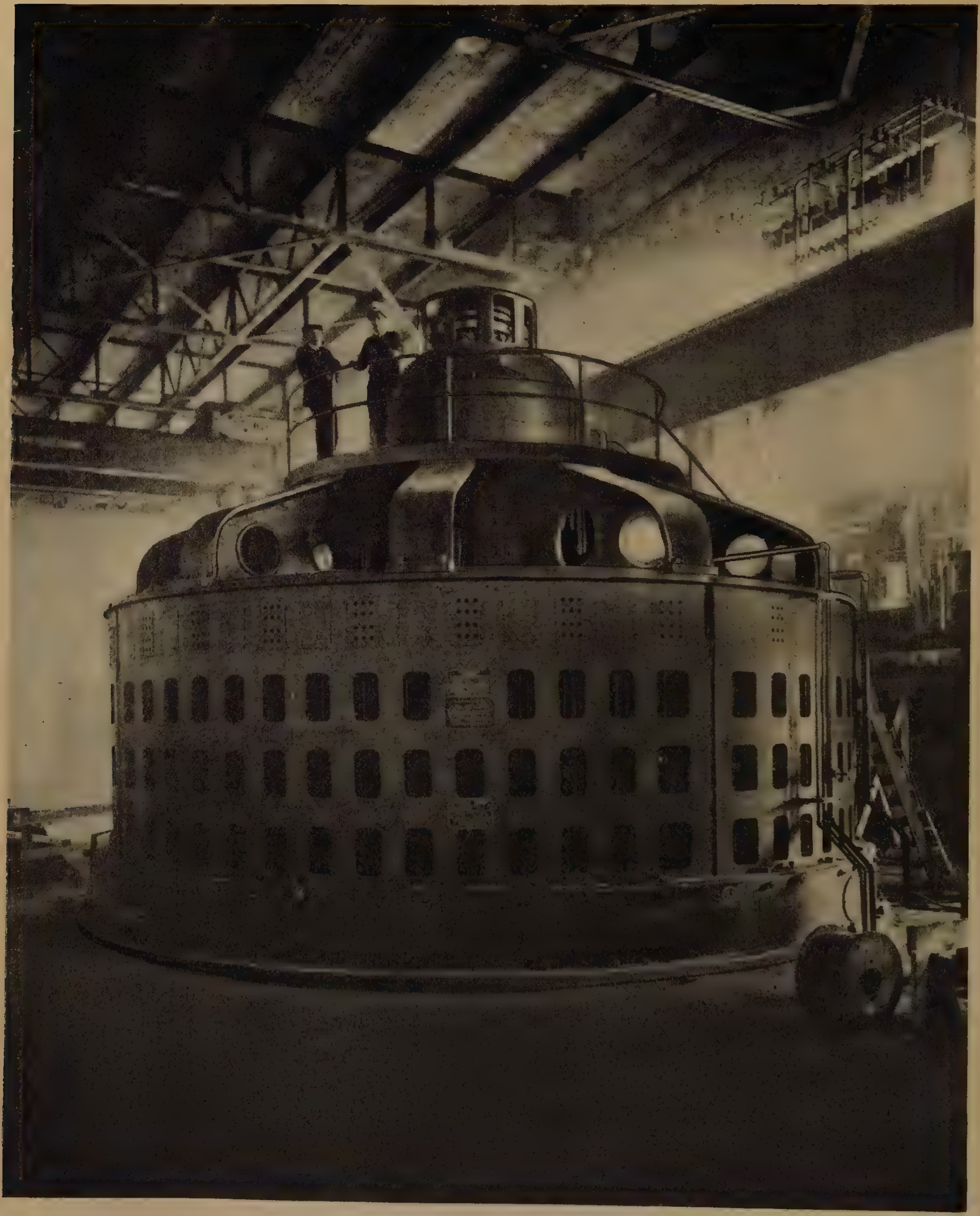


Fig. 17. Assembled Generator in Power Station

between the poles at the center of the field coil. These heavy field coils are heated and clamped to size as shown in Fig. 16.

Brakes

Twelve air operated brakes are mounted on a very rigid continuous supporting ring imbedded in the concrete. These brakes operate at a pressure of approximately 100 to 125 lb. per sq. in. and stop the rotor having a WR^2 of 65,000,000 in approximately five minutes. The so-called brakes are really a combination of brakes and jacks so that, in dismantling the generator, the entire weight of the generator rotor and waterwheel can be supported on them. When used for lifting purposes, they are operated by a Watson-Stillman high-pressure hand-operated oil pump at a pressure of approximately 1500 lb. per sq. in. All the piping for the combination brakes and jacks is extra heavy to withstand this pressure.

A control valve for the brakes is conveniently located on the operating gallery.

Oiling System

Each unit is equipped with its individual oiling system consisting of a motor-operated oil pump and Richardson-Phenix oil filter. The induction motor is rated ¼ h.p., 3-phase, 220 volts, 25 cycles, and 750 r.p.m. The pump will furnish the required amount of oil for the guide bearing and in addition a small flow for the thrust bearing in order that it may be kept clean. Heat from the thrust bearing is removed by means of water circulated through copper cooling coils. Approximately 50 gallons of water per minute are required. Provision is also made so that oil can be supplied from the station oiling system. Recording thermometers indicate the temperature of the oil in the thrust bearing and also the temperature of the guide bearing.

Ventilation

Air for ventilating the generator is taken in at the top and from the pit underneath the machine in about equal quantities and will be discharged into a housing surrounding the machine. Approximately 125,000 cubic feet per minute will be required. An exhaust fan is provided so as to insure the proper flow of air under all weather conditions.

Fire Protection

A novel feature for stopping the swirling air at the heads of the machine, due to the throwing off of the air from the rotor, and also to insure a change of air, consists of specially designed vanes of bakelite canvas. These are made in short sections and are attached at the top and bottom of the machine near the stator coils. In case of fire, these vanes will tend to confine it to the immediate spot.

Excitation Generator

Fig. 14 shows the stator of the generator that furnishes power for the exciter sets and auxiliaries. It is supported just beneath the upper bearing bracket. The rotor is mounted on the upper section of the field spider arms of the 65,000-kv-a. machine. The rating of this excitation generator is 650 kv-a. or exactly one per cent of the main generator. It is of 2200 volts, 25 cycles, 3-phase and has the following temperature guarantee: 650 kv-a., 0.8 p-f. continuous operation, 50 deg. C. rise by thermometer on the stator and 55 deg. C. rise by resistance detectors of which there are six in the winding. The temperature guarantee on the rotor is 55 deg. C. by resistance. The armature coils have more than the usual thickness of insulation for this voltage.

This generator is so designed that the poles may be removed between the arms of the upper bearing spider of the main generator. With this arrangement, it is possible to replace armature coils from this excitation generator by removing a sufficient number of poles without dismantling any of the parts of the main generator except the covers between two of the arms of the bearing bracket.

Weights and Dimensions

The approximate total weight of the unit complete is 1,500,000 lb.

The outside diameter of the base ring is 31 ft. 10 in. and the total height from the floor line to the top of the generator is 26 ft. 4½ in. Fig. 17 shows the assembled generator in the power station.

Epoch Making Tests on New Passenger and Freight Locomotives

By W. D. Bearce

Railway Engineering Department, General Electric Company

The author describes some interesting tests carried out at the Erie Works of the General Electric Company on two electric locomotives. These tests, which were in the nature of a public demonstration, took place on December 4 and 5, 1923. The testing facilities are described and the principal features of the two locomotives are given. One of the notable events of the demonstration was the attainment of a speed of 105 miles an hour by one of the electric locomotives.—Editor.

From its earliest history the idea of rail transportation has possessed an attraction amounting almost to a fascination for people in every walk of life. Even in its early operation the steam engine showed such marvelous superiority over the horse-drawn vehicle that it was classed in the old days with the supernatural. With the far more wonderful improvements and refinements which go to make up a modern transportation system, interest in railway achievements is well-nigh universal.

In more recent years the use of electricity for train haulage has become an important factor in railroad transportation. Increased possibilities in the design of engines of high speed and great power have popularized this type of motive power and have given added attraction to this vital industry.

Therefore when the General Electric Company announced a public exhibition of a new high speed passenger locomotive, together with load tests of an unusually compact and powerful freight engine, a gratifying response was received from railroad men throughout the country. A total of about 125 railroad officials were present in person representing more than 30 roads. Regrets from many high officials indicated keen interest in these new locomotives.

The occasion of the exhibition was, first, a demonstration of the new passenger locomotive built for the Paris-Orleans Railway. This unit was guaranteed to operate successfully in regular service at speeds up to 81 miles per hour. During a test run made on December 2nd, a sustained speed of 105 miles per hour was reached and even at this speed the locomotive showed remarkably easy riding qualities.

The second attraction was the new 150-ton freight locomotive, which is part of an order for the Mexican Railway Co. This locomotive concentrates a total of 2736 horse power in a single cab unit or 5472 horse power (hour rating) for two units operated in multiple by one engineer.

An added interest was inspired by the use of a modern steam locomotive as an ocular demonstration of the power of the new electric design.

Not only was interest aroused in railroad men but among the travelling public all over the world. In the United States alone more than 300 newspapers carried accounts of the exhibition. New York dailies published front page articles and the Associated Press dispatches featured the various tests. As a feature of the exhibition records of all tests were made with a new device called the otheograph, for recording the action on the rails of each separate wheel of a locomotive or motor car. Both of the electric locomotives were manufactured jointly by the American Locomotive Company and the General Electric Company.

Testing Facilities at Erie Works

The track used for testing purposes at the Erie Works consists of about four and one quarter miles of road, which is a portion of the eastern division of the East Erie Commercial Railroad. An overhead catenary construction is installed and power is supplied from a substation having a total rated capacity of 2500 kw.

The portion of the track used for high speed running is about two and one half miles in length, the remainder being used for accelerating and slowing down the train. Included in this high speed section there is one mile of level tangent track. East of the tangent there is a light ascending grade with curves of from one to one and one half degrees. The rail weighs 100 lb. per yard and is laid with 24-in. tie spacing in slag or stone ballast.

Paris-Orleans Locomotive

The particular features of design which adapt the Paris-Orleans locomotive to unusually high speed running are, first, the gearless motor, and second, the special designs which are used in the leading and trailing trucks. The gearless motor drive removes the restrictions as to permissible armature speed which sometimes limit the safe speed of a locomotive.

By the use of the bipolar gearless motor, which is used in this locomotive, the armature and fields are allowed a vertical movement entirely independent of each other. The field magnets and windings are carried on the spring supported truck frame, while the armature is carried on the axle, and the only dead weight resting on the track is that of the wheels, axles and armature. This weight is well within the dead weights which are recognized as good practice on steam locomotives.

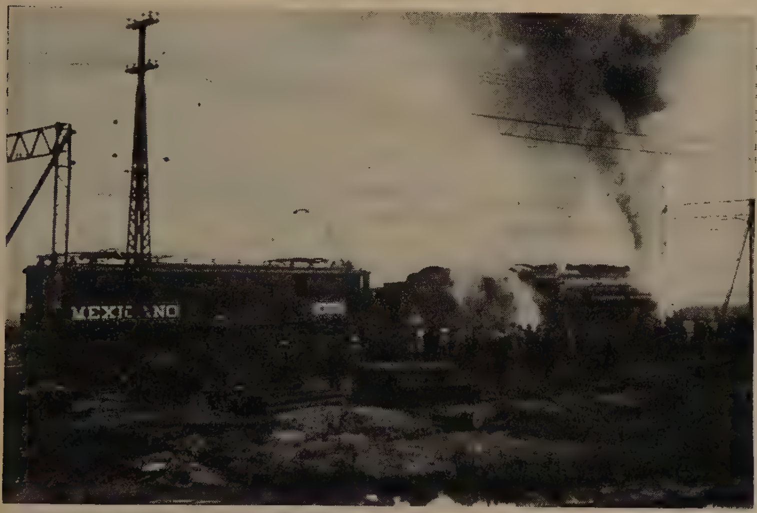


Fig. 1. Tug-of-war Between Electric and Steam Locomotives

An important feature of the truck design is the type of centering device. The weight of the outer end of the cab is carried on two rollers, which rest on inclined planes attached to the truck near the drawbar. Any lateral motion of the truck causes one or the other of these rollers to move up the corresponding inclined surface, thus lifting the weight of the cab and transferring this weight to the rail against which pressure is being exerted. As the roller returns to its normal position, the cab quickly comes to rest at the center point and the design thus avoids the tendency to oscillation, which in many types of locomotives limits the maximum speed attainable. Numerous tests have demonstrated that any tendency toward periodic oscillation is immediately damped out by the action of this device.

This locomotive will be required to handle trains on the six-track and four-track sections of the Paris-Orleans Railway running from Paris to Vierzon, which is now being electrified. The existing schedule on this line calls for maximum speeds of 80 miles per hour by steam locomotives.

The General Electric Company has successfully designed a number of high speed passenger locomotives which use the bipolar gearless motor. The first of these was the initial order for the New York Central Railroad Company handling passenger service out of the Grand Central Terminal. These locomotives were guaranteed to operate at 75 miles per hour, but were tested up to 85 miles per hour. The second order for the New York Central Railroad Company also employed the gearless motor using eight motors instead of four, and having motors on the leading and trailing trucks as well as on the main driving wheels. This type was also guaranteed for 75 miles per hour and tested at 85 miles per hour. The third type of gearless locomotive was built for the Chicago, Milwaukee & St. Paul Railway and this was guaranteed to operate successfully at a speed of 65 miles per hour. In a demonstration, however, made by the Railway Company for the benefit of a commission from the French Government, a speed of 82 miles per hour was reached by this locomotive operating over a sand ballasted track.

With the experience obtained in the building of these high speed locomotives, the designers felt no hesitancy in making a contract with the French Company for a locomotive capable of running at 81 miles per hour. The final tests during which a sustained speed of 105 miles per hour was reached are convincing evidence of the thorough success of this design.

The demonstration on December 4th and 5th included several runs starting from the west end of the test track, passing through several curved sections and a long tangent; a total distance of about four miles. Visiting railroad men and engineers were carried in the two cabs of the locomotive. An inspection run was made, first, to check up the condition of the track. The locomotive was then run back to the west end and accelerated rapidly on several runs reaching a speed of 62 miles per hour in 50 seconds. The first run was made at about this speed giving an

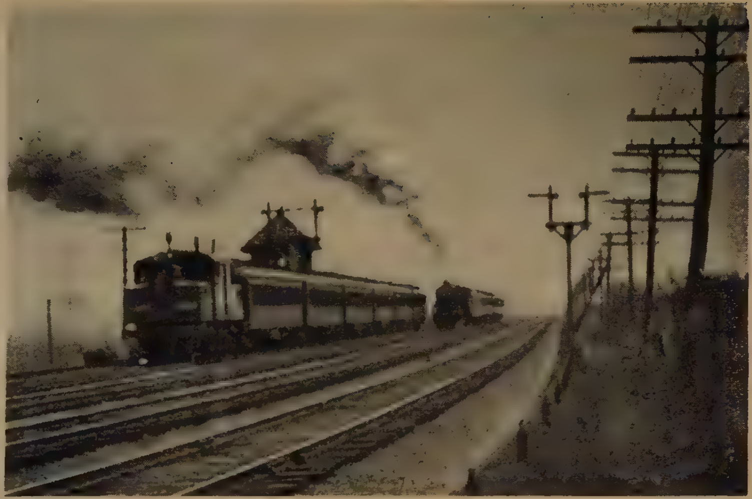


Fig. 2. Speed Test Made in November, 1904, Between Electric Locomotive No. 6000 and a New York Central Steam Locomotive

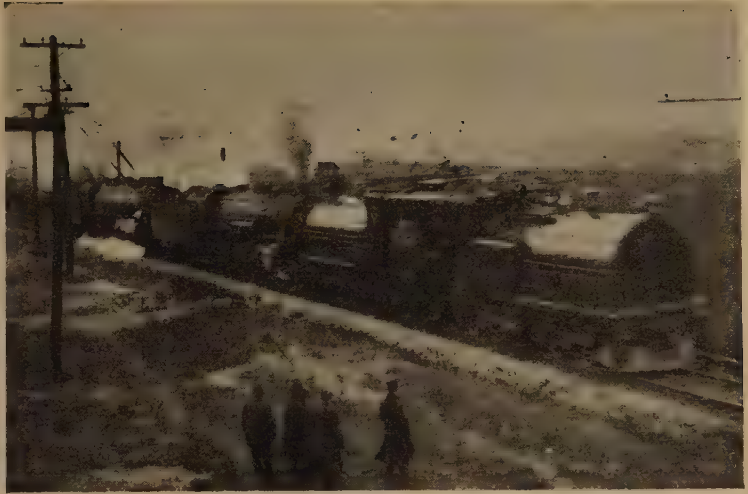


Fig. 3. Regenerative Braking Test Made in November, 1919, on a C. M. & St. P. Gearless Passenger Locomotive

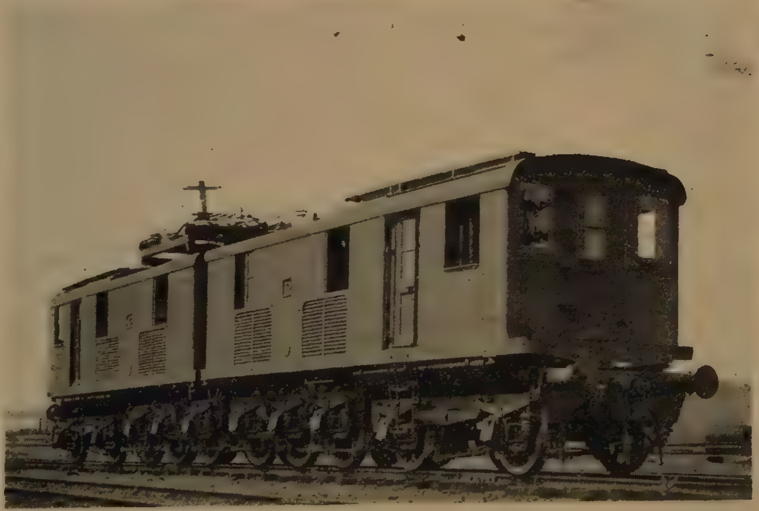


Fig. 4. Paris-Orleans 1500-volt Passenger Locomotive which displayed remarkably easy riding qualities at a speed of 105 m.p.h.

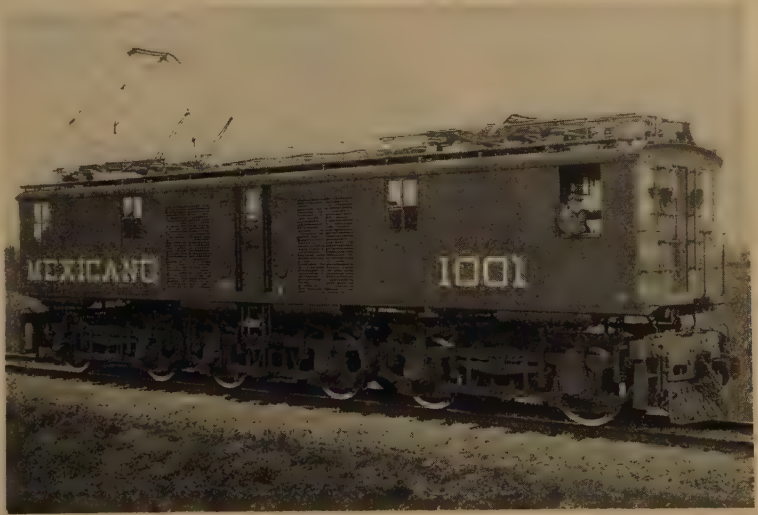


Fig. 5. The First of Ten 150-ton 3000-volt Electric Locomotives Built for the Mexican Railway Co., Ltd., to replace more than twice that number of 150-ton Double-ended Steam Locomotives having all weight on drivers

opportunity to judge the riding qualities at 60 miles per hour. A second run was then made starting at the same point and accelerating to approximately 150 km. (93 m.p.h.). The locomotive was stopped on the return trip to allow visitors to inspect the otheograph, and a new party was taken aboard the locomotive for another run.

Several high speed trips were made to accommodate all of the visitors wishing to ride on the locomotive. On several of these trips, speeds as high as 97 miles per hour were recorded during the demonstration. The record run when 105 miles per hour was reached was made on December 2nd, carrying Mr. Potter, Chief Engineer of the Railway Department; Mr. Batchelder, the designer, and a number of other engineers. The riding qualities of the locomotive at this speed were pronounced to be unusually good. An appreciable movement of the cab occurs at high speeds, due to the action of the roller centering device, which operates when any lateral movement of the trucks occurs, and thus cushions the blow of the flange against the rail. Engineers familiar with high speed locomotive operation commented very favorably upon the fact that a locomotive capable of operating in either direction showed such excellent riding qualities.

Fig. 6. Group of Railway Engineers at Erie, Pa., Discussing the Tests. Left to right: A. F. Batchelder, W. B. Potter, B. L. Delack, B. J. Arnold

Tests on Locomotive for Mexican Railway Co., Ltd.

The geared freight locomotives built for the Mexican Railway Company, Ltd., are chiefly remarkable because of the high capacity per unit obtained by using three 2-axle trucks under each cab. These locomotives have a total one-hour blown rating of 2736 h.p. and a corresponding tractive effort of 54,000 lb. at 19 miles per hour. Owing to the distribution obtained by using six axles with two driving motors on each truck, the moderate weight of 50,000 lb. per axle is secured. Two of these units operating in multiple, as will be required in the freight service on the Mexican Railway, will give the equivalent of a 5040-h.p. locomotive having a continuous tractive effort of 97,000 lb. at 19.5 miles per hour.

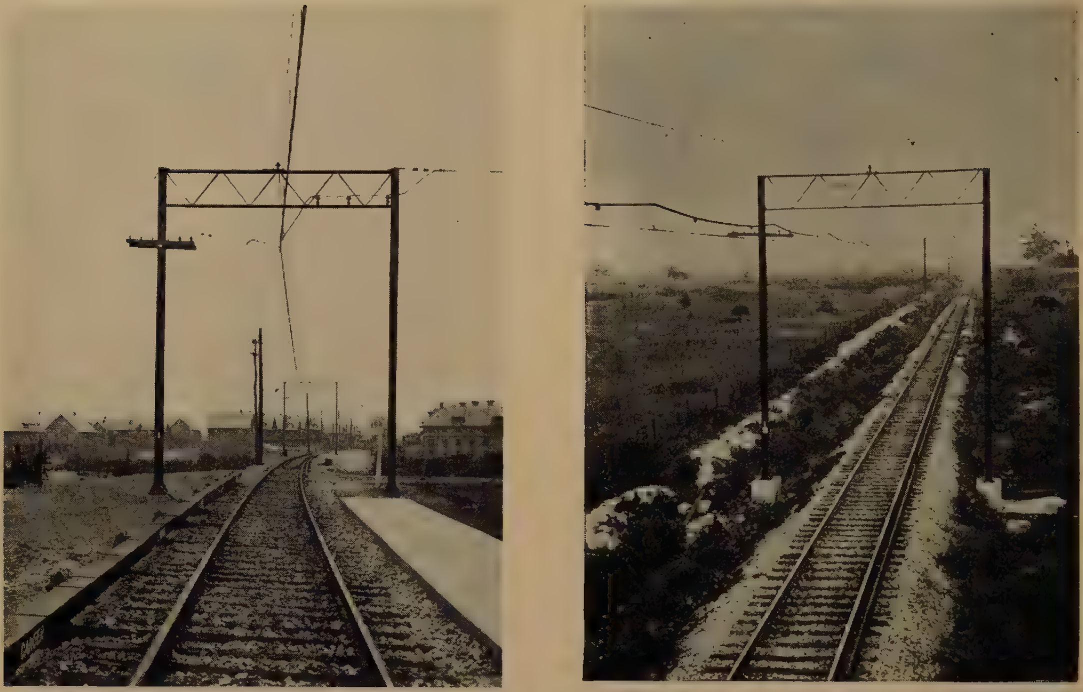
In order to make a conclusive demonstration of this locomotive, a number of tests were carried out on December 4th and 5th including the following:

1. A trip at 40 miles per hour carrying trailing coach for otheograph record.
2. Operation at various speeds with steam locomotive furnishing power for regenerative electric braking.
3. A tug-of-war test with steam locomotive of approximately the same tractive weight.

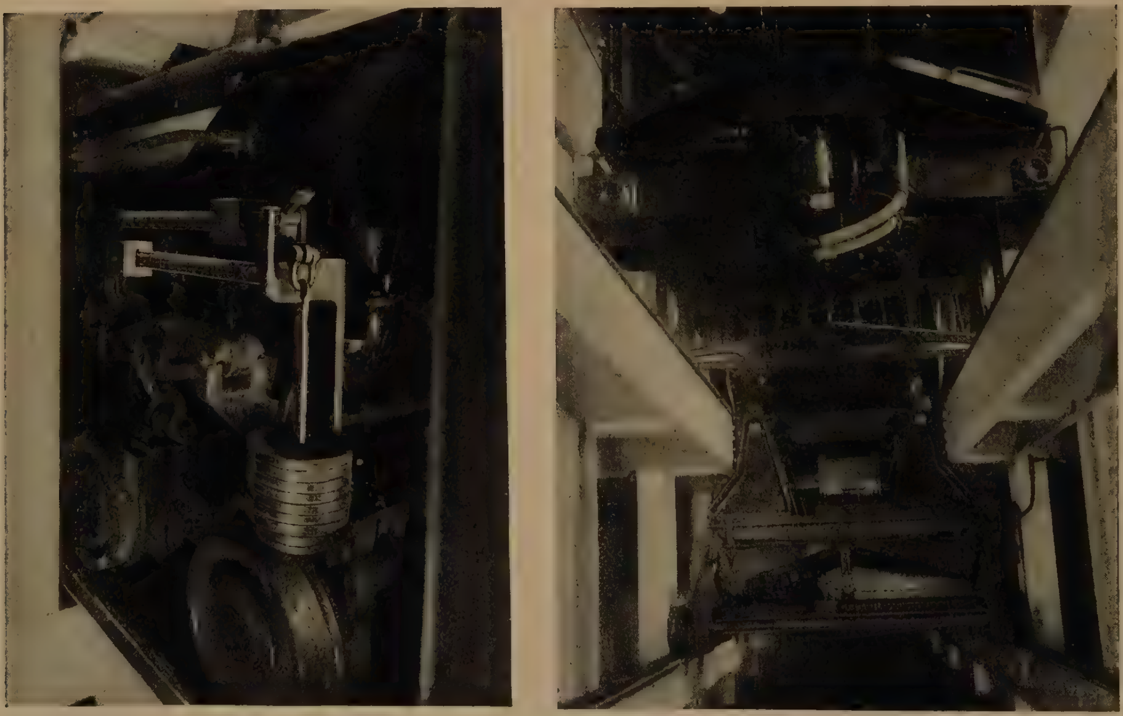
The initial run at 40 miles per hour carried visiting railroad men and engineers both in the cab of the locomotive and in the trailing coach. Favorable comments were made on the riding qualities of this locomotive at a speed of 40 miles per hour, although the truck arrangement does not include guiding wheels. A number of the visitors left the train at the otheograph station in order to witness the making of records on this device for the various succeeding runs.

Regenerative Braking Tests

For the regenerative electric braking tests the steam engine and the Mexican electric locomotive were coupled together and started from the west end of the track. The first run was made at 8.7 miles per hour, regenerating approximately 810 kw. The calculated drawbar pull on this trip was 57,640 lb. The first operating position on the electric locomotive was used placing all motors in series, while on the steam locomotive the booster engine was continuously in operation. On the second run the train was allowed to reach a speed of about 15 miles per hour before regenerative braking was applied. A speed of 15.5 miles per hour was then maintained by regenerative braking control, sending back approximately 1080 kw. to the substation. The drawbar pull calculated for this run was 42,330 lb. On the third run the speed held by



Figs. 7 and 8. Right-of-way of High-speed Test Track showing Overhead on Curved and Tangent Sections



Figs. 9 and 10. Views of Locomotive Weighing Scales at the Erie Works Used to Obtain Detail Weights of Electric and Steam Locomotives Tested. Left, weighing beam and air hose connection; right, pit with locomotive on scales the electric locomotive with the motors in parallel was 23.6 miles per hour. The amount of power regenerated was 1620 kw. and the calculated drawbar pull 40,450 lb. The following table summarizes the conditions under which these three tests were made.

SUMMARY OF REGENERATIVE BRAKING TESTS

Run	Speed MPH.	Kw. Regen.	Calc. Lb. Drawbar Pull	Motor Connection	Steam Engine
No. 1	8.7	810	57,640	Series	With Booster
No. 2	15.5	1080	42,330	Series Parallel	No Booster
No. 3	23.6	1620	40,450	Parallel	No Booster

During these tests the electric locomotive was not at any time loaded to full capacity. Tests had previously been made, however, using two electric locomotives (one motoring and the other regenerating) demonstrating satisfactory operation at full load.

Tug-of-War Tests

In order to obtain a comparative test of the relative merits of geared drive as used on the electric locomotives and the coupled side rod construction used by the steam locomotive, a tug-of-war contest was staged using a Mikado steam locomotive. The total weight of this engine on the drivers, including the booster, at the time of the tests was 309,300 lb. as compared to a scale weight of 309,650 lb. for the Mexican locomotive. The two locomotives, therefore, were approximately on an equal basis as regards weight on driving axles. The test was first started from a standstill, power being applied to both engines at a given signal. The electric locomotive had no difficulty in holding the steam locomotive and then pulling it backward. Other tests were made during which the steam locomotive was allowed to reach a low speed, and even with this advantage the electric had no difficulty in stopping and hauling the steam engine backward. Favorable comments were made on the effectiveness of the equalization of the electric locomotive running gear which permitted the use of a tractive coefficient as high as 30 per cent when moving without slipping the wheels. In all of these tests the rail was well sanded before trial. From readings taken of the current used by the electric locomotive the drawbar pull exerted was calculated as follows:

Balanced drawbar pull at standstill	86,000 lb.
Electric locomotive hauling Mikado backward	94,000 lb.

Steam Locomotive Tests

In addition to the regenerative braking and tug-of-war tests an opportunity was afforded to obtain otheograph records of the steam locomotive operating at several speeds. The first run was made at 5 miles per hour to give a record corresponding approximately to static weight. The locomotive was then run over the otheograph at a speed of 30 miles per hour both forward and backward. The final run was made at 60 miles per hour. Some special runs were made including a trip at 30 miles per hour making a heavy application of the brakes when passing the otheograph. At the request of one of the the New York Central officials a speed trial was made with this locomotive during which it was shown to be capable of making 70 miles per hour.

This steam engine was built by the American Locomotive Company and is up-to-date in every particular, being equipped with booster, superheater, feed-water heater and mechanical stoker.

Following are some of the principal data:

Boiler pressure	210 lb. (392 deg. F.)
Diameter of cylinders	28 inches
Stroke	30 inches
Max. tract. power (engine)	66,600 lb.
Max. tract. power (booster)	11,500 lb.
Diameter of drivers	63 inches

(*The following are the American Locomotive Company's weights*:)

Pilot truck	29,000 lb.
Total weight of engine	335,000 lb.
Weight on main drivers	248,000 lb.
Weight on booster truck	58,000 lb.
Weight on drivers and booster truck	306,000 lb.
Weight of tender	200,300 lb.
Average weight upon driving axles (including booster)	61,200 lb.

Street Traffic Control Apparatus

By G. F. PRIDEAUX

COMMERCIAL ENGINEERING DEPARTMENT, EDISON LAMP WORKS, GENERAL ELECTRIC COMPANY

"How simple the problem of traffic control would be if all drivers and pedestrians were automatons! But they are not and all the vagaries of human nature must be considered in its solution." Mr. Prideaux might have added: "How simple would be the problem if all the units to be controlled were of the same size and speed! But they are not; they range in size from a small child to a ten-ton truck and vary in speed from the limping gait of a cripple to the rush of the high-powered pleasure car." Then, too, the problem varies with the location; the busy downtown section, the residential district, the park boulevards, and the highway and railroad crossings. Some of the types of apparatus which have been developed to promote safety and expedite traffic movement are described in the article below.—EDITOR.

Automobile license registrations show that there were 500 cars on the city streets of the United States in 1903, and in 1912 there were 800,000. This number was increased to 10,500,000 in 1921, which amounts to an annual increase of 13 per cent, or more than a million automobiles. As a result the streets in every city are so crowded with automobiles that the regulation of traffic is a real problem. To relieve congestion most police departments regulate parking and institute one-way traffic on certain streets to avoid tie-ups; but to reduce accidents, collisions, and even fire hazards that may result from traffic congestion, the signals of each traffic officer must be seen, understood, and obeyed by everyone.

Control by a single mind rather than many is the best preventative of confusion among these masses of vehicles and people. It is to aid and make possible this control by a single mind that street traffic control apparatus has been designed. The underlying theory, i.e., halting the traffic in one direction and permitting its flow in the other, is relatively simple. In practice it is very complex. How simple the problem of traffic control would be if all drivers and pedestrians were automatons! But they are not and all the vagaries of human nature must be considered in its solution. The traffic officer stationed at street intersections is but the nucleus of street traffic control. His one mind directs the actions of many for the benefit of all. His effectiveness is limited by the number of people he can control and the rapidity and clearness with which his intentions and signals reach them.

The old-time traffic officer who came into being when automobiles first became popular did no more than stand at street intersections and direct traffic with his arms. Later he was supplied with a whistle, which is still a part of his equipment in many places. The position of traffic officer in those days was given as a reward for good conduct and was looked upon more or less as an easy berth. This has changed and the present traffic officer must be an intelligent man who in addition to directing vehicular traffic must also be able to deal with the public with as little friction as possible.

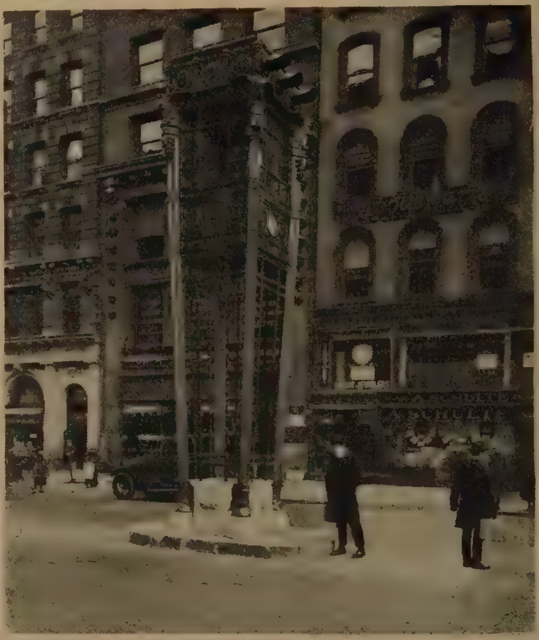


Fig. 1. Fifth Avenue Traffic Tower, New York City. The time of traffic flow in each direction is automatically regulated

Object of a Traffic System

The object of a traffic system is two-fold. It is to permit the movement of traffic with safety to all and to give the greatest facility for speed. By careful analysis and much observation it has been shown that the minimum confusion results when the intersections are at right angles. For maximum safety all traffic should move parallel to or at right angles to one another. Increasing or decreasing this angle results in an increase in confusion.

A pedestrian crossing a street looks first to the left and then to the right. After this assurance of a safe crossing he saunters or hurries across, according to his temperament, looking only straight ahead. His angle of vision is not greater than 100 deg., 50 deg. on each side. He certainly will not see or suspect a car cutting the corner and approaching from the rear at high speed until it strikes him. It is said that 90 per cent of all traffic accidents to pedestrians occur in this manner.

There are two means by which a traffic officer's direction may be conveyed, viz., by audible and visible signals. Of the two, visible signals are more effective, but where both can be embodied this is certainly to be recommended. The traffic officer who is not aided by modern equipment is greatly handicapped in his work. His whistle is often drowned by noise and in dense crowds his signals cannot be seen.

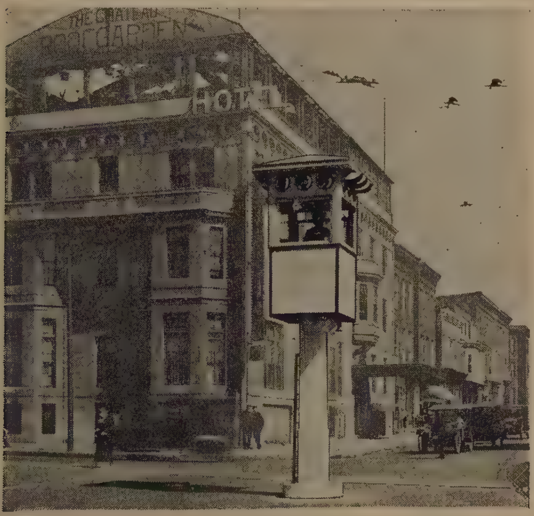


Fig. 2. Baltimore Traffic Towers are typical of many that are used

Modern Street Traffic Control Apparatus

Modern street traffic control apparatus has been designed and developed with a view to aiding the directing mind of the traffic. The simplest and most effective apparatus employs the use of brilliant colored signal lights so placed that they command the attention of all for a distance of several blocks.

The city heading the list of complete and scientific installations is New York and the best installation, Fig. 1, is that on Fifth Avenue. There will be seven such towers when the installation is completed. Miles of traffic on Fifth Avenue and on streets for several blocks on either side are controlled by this one mind or officer in the master tower.

A few other cities that have similar traffic control but less elaborate are: Detroit, Philadelphia, Baltimore (Fig. 2), Knoxville, Houston, Milwaukee, San Francisco, and New Orleans. It is very surprising, however, to know that Washington, Chicago, Minneapolis, St. Louis, Newark, and a few other large cities have no other traffic control apparatus than perhaps a small mechanical semaphore.

In New York City the towers are mounted in the center of the avenue, five blocks apart. Reflectors direct the light signals up and down the avenue. The signals cannot be seen on the cross streets, but the flow of traffic is so dense on the avenue that cross street traffic can move only when the avenue traffic has stopped.

The wiring for these towers is in conduits in the street and the source of power is the municipal lighting circuit. Telephone communication is maintained between towers. All signals are operated simultaneously from the master tower at 42nd Street. An electromagnet operated shutter controls the various color lenses in front of the reflectors. Two spare reflectors or units are maintained on each side in the tower. The lamps previously used in the old towers were 500-watt, 120-volt, concentrated-filament floodlight lamps, mounted in floodlights. Three floodlights having different colored lenses were mounted in a row. The lamps flashed on and off according to the color signals desired. This subjected them to the strain of being switched on and off about 1000 times a day.

With the present arrangement, which includes an efficient reflector, a 23-watt 120-volt concentrated filament street railway headlight lamp may be used. (The wattage may be increased to 40.) The lamps are burned continuously. The cost of the tower was approximately $14,000, only one-fifth of this amount being necessary for the electrical equipment. Other types of traffic towers are similar in that they consist of a crow's nest or housing for the officer and an array of signals. They usually give indications in four directions, however, and are located at the centers of street intersections.

Due to the rigid economy that is necessary in most cities the elaborateness of the Fifth Avenue tower is not attempted. In cases where street car tracks make it impossible to place traffic towers in the center of the street intersections, lanterns embodying the same principles may be employed by suspending them on cables. In some cases it is felt that neither of these systems are suitable and recourse has been had to a third type of signal such as is used in the city of Houston, Texas. These are purely one way signals and four such units are placed on towers or poles at each corner of the intersection.

Interlocking of Signals

In cities having a number of traffic towers on one street or where the congestion extends for several blocks, it is well to have the signals operate in synchronism by interlocking the lamp circuit, Fig. 3. This will give the best traffic flow and prevent any personal animosity, that might be held by an officer, from interfering with the performance of his duty. Such cases have been noticed where one officer, holding a grudge against the next, permitted the traffic to flow down on him whenever possible.

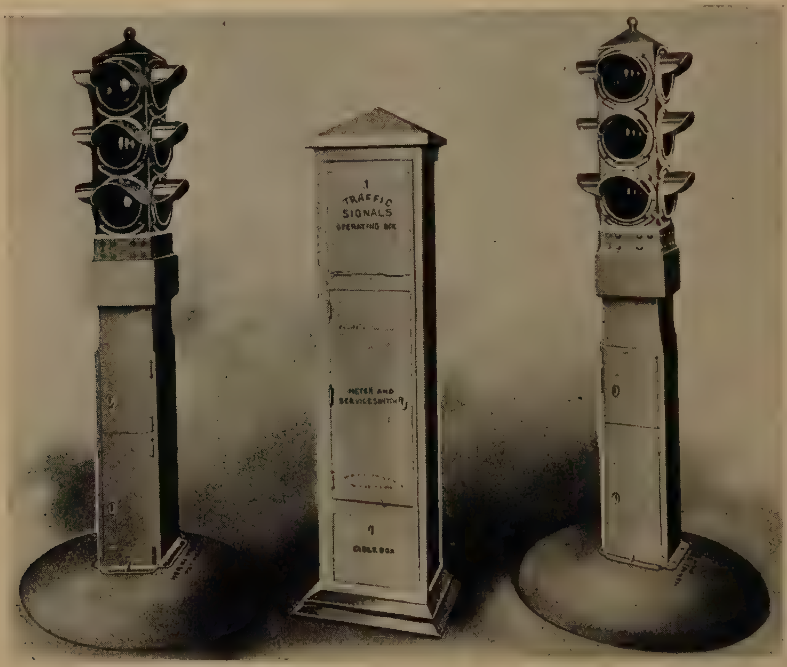


Fig. 3. A Traffic Signal that can be Operated Either Automatically from a Central Control Point, or by an Officer Stationed at the Curb. The signals shown are of the portable type, and may be removed from the street when desired

Semaphore Installation

Where the installation consists only of a mechanical semaphore, Fig. 4, operated by a traffic officer it is necessary to provide sufficient illumination so that his signals will be effective at night. This can be done by hanging projectors or flood lamps directly above or on convenient buildings and flooding the officer and signal with light. It has been found that 500-watt 110-volt concentrated filament floodlighting Mazda lamps are well suited for this purpose, when used in the Novalux unit shown in Fig. 5.

Placing of Obstructions to Direct the Flow of Traffic

Obstructions properly located in the street serve to direct the flow of traffic. To make the best way the easiest way, it has often been necessary to block off certain sections of streets or to place obstructions such as concrete safety isles (Fig. 6) to force drivers to take the proper course around the center of the intersection. This eliminates the very dangerous condition in which a driver at high speed makes a cut, as shown in Fig. 7A, which produces a wide angle of confusion with traffic flowing on the street he is turning into and he approaches pedestrians crossing the street from behind and takes them unawares.

The simplest and easiest case to deal with is that of a three-way street having no street cars, Fig. 7B. To prevent cutovers and have traffic intersect at right angles, a large flashing electric beacon and safety isle should be placed in the center of the intersecting street and up to the street line of the continuous street.

It is the left-hand turn that is dangerous, Fig. 7C. A turn to the right can be made with comparative safety at low speed. A brilliant flashing signal in the line of vision will effectively serve to reduce the speed of an approaching car so that either right or left turns will be made at low speed.

Four flashing units placed as indicated in the diagram of a four-way street intersection, Fig. 7D, is a very good method of making the easiest way the best way. This arrangement is particularly to be recommended in outlying sections where the traffic is not too dense.

Where street cars intersect at right angles and dense traffic prevails, it is impossible to place an obstruction or beacon in the center of the streets as in the cases considered previously. The traffic tower is also barred as there is not room between the tracks for its erection. The best solution of the case where the width of the streets permits would be to use the two features of a traffic system, that of controlling the traffic movement and of directing its flow into safe channels. Fig. 7E shows a layout that will accomplish these results. The safety isles present an obstruction that will prevent diagonal cuts and make all intersections at right angles. This affords pedestrians the maximum safety and facilitates the intersecting movement of traffic.

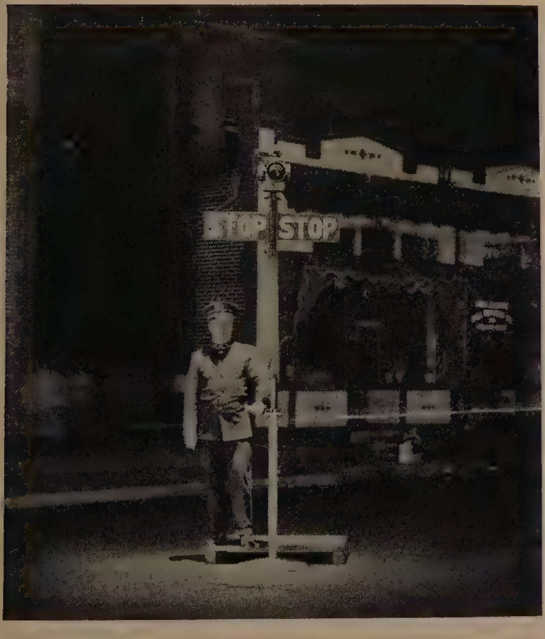


Fig. 4. This Mechanical Semaphore Shows One of the First Methods of Signalling Traffic. The signal and officer are illuminated at night by an overhead reflector

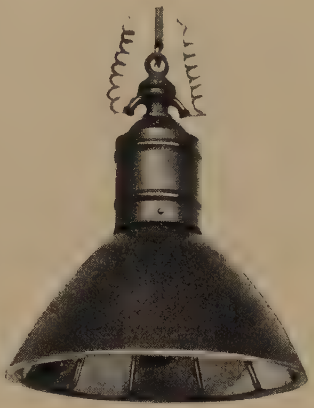


Fig. 5. Novalux Unit with 500-watt Mazda C Lamp for Suspension above a traffic officer

Daylight signal beams of light are sent down the street by units which are mounted about 15 ft. high on poles on the far side of the street. The poles stand on the corner and the arm which carries the signal is suspended 6 or 7 ft. out over the street.

Physical Requirements of the Units

The main requirements for traffic control lighting units are that they shall be weatherproof, contain a lens which has the property of resisting the heat from the lamp, and a concentrating reflector of high permanent efficiency to produce a good beam of light that will be visible at a distance of 1000 ft. The color in the lens should be permanent.

The control of these signals may be accomplished by means of a flasher similar to those used on electric signs. For the ordinary case the time of traffic flow may be adjusted to the particular need of the location, but in case the traffic is more variable it may be operated by the officer in charge.

The City of Milwaukee has found that the automatic electric signals for traffic regulation which are located out of the busy downtown section are very useful for avoiding accidents. They are also efficient in that they save the services of traffic officers who would otherwise have to be stationed at intersections. However, from experience with these signals when used on busy streets having car lines, the

City finds that a traffic officer must be on duty with the signal all of the day and the greater part of the night. This may be chiefly due to the fact that the kind of signal used was, of necessity, of the suspension type and was not very satisfactory because of its height.

Fig. 6. Properly Located Safety Isles are an Excellent Means for Directing the Flow of Traffic

Outlying Districts and Boulevards

The tendency of traffic departments in the larger cities is to lay out a system of boulevards or arterial highways leading out from the center of the city so as to take care of the congestion of traffic during early morning hours and at night. In order to make these boulevards and highways fully serve their purpose, it is necessary to give traffic on them the right of way over cross streets. They increase the average speed of traffic and help to clear up congestion. In order to give this right of way, an ordinance is usually passed requiring vehicles crossing the boulevard to come to a stop before crossing or turning into them. During daylight a "Stop" sign is sufficient but after dark some other means must be used to warn the public to come to a stop or accidents will occur. The usual traffic light is not suitable since the driver, while considering the intersection important, will not stop. If a different color light is used, say a red light, the motorist will stop, but the driver on the boulevard will also either stop or else will disregard the signal, which is poor practice.

To overcome this condition, units have been developed that when lighted show different colors in different directions. The usual arrangement is to show amber or green in one direction, say north and south, and show red toward the east and west. A "mushroom" beacon of some such character as that shown in Fig. 8 is set in the center of the boulevard or arterial highway and shows green or amber up and down the boulevard, but when approached from a side or intersecting street, shows red. As a result drivers on the boulevard will know where the street intersections

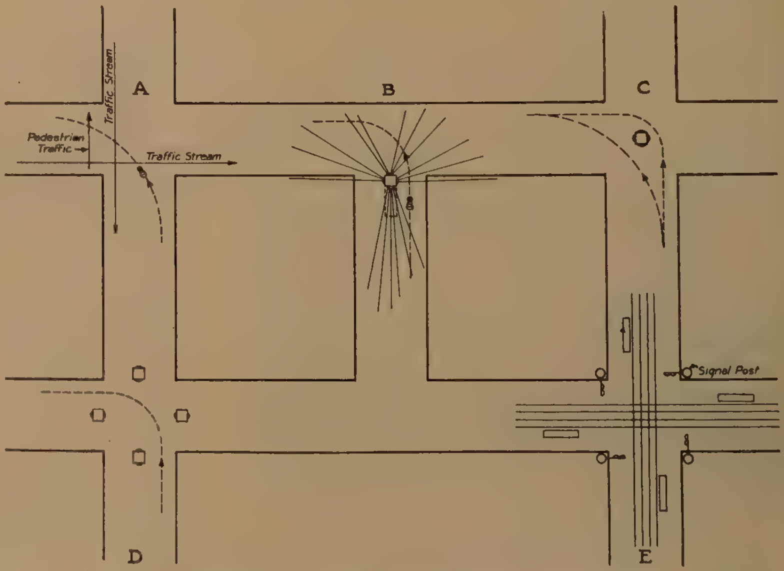


Fig. 7. Means of Reducing Accidents at Street Intersections:

(*A*) shows the very dangerous condition in which a driver at high speed may cut across a corner. He approaches one line of pedestrian traffic from the rear and intersects two lines of traffic at other than right angles, which produces great confusion. If a flashing electric crossing beacon is placed as in (*B*), it serves to slow down the speed of an approaching car, prevents diagonal cuts, and provides a safety isle for pedestrians. The flashing electric light placed at the center of the intersection as in (*C*) serves to reduce the speed and the majority of cars will pass around the beacon. The careless driver, however, is not prevented from cutting across the corner. Four beacons placed as shown in (*D*) will reduce car speed to a safe value, prevent cut-overs and provide safety isles for pedestrians. Safety isles (*E*) prevent cutovers and afford pedestrians a safety zone. Signal lights mounted on posts on the far corners of the street control the movements of traffic.

occur and yet will drive on by, while drivers approaching on the intersecting streets will obey the signal and bring their cars to a stop before driving on the boulevard.

Points to be Considered in Deciding Upon the System to Use on Boulevards or Outlying Districts

(1) Danger of accidents due to marker
(2) Conspicuousness of the marker
(3) Reliability of the marker
(4) Upkeep and maintenance cost
(5) Artistic appearance.

Flashers of the type shown in Fig. 9 are mounted on a concrete base weighing about a ton and located so as to form a heavy obstruction to eliminate diagonal cutting of the corner. They are white with black lettering. This color combination is sufficiently striking to be an adequate daylight signal. Their flashing feature is very useful. It has been proved by extensive tests that a flashing light is many times more attractive and commanding than a still light of the same intensity. Danger from accidents is reduced by the large size of the flasher commanding strict attention.

The mushroom type of traffic or boulevard light is well adapted for this purpose, in that danger from accidents due to the marker has been practically eliminated. Four 50-watt mill type lamps are used in each boulevard beacon. This type of lamp is desirable for mounting in the units because of its small overall length and substantial construction which withstands vibration. The unit will clear itself of snow due to the heat developed by the lamps.

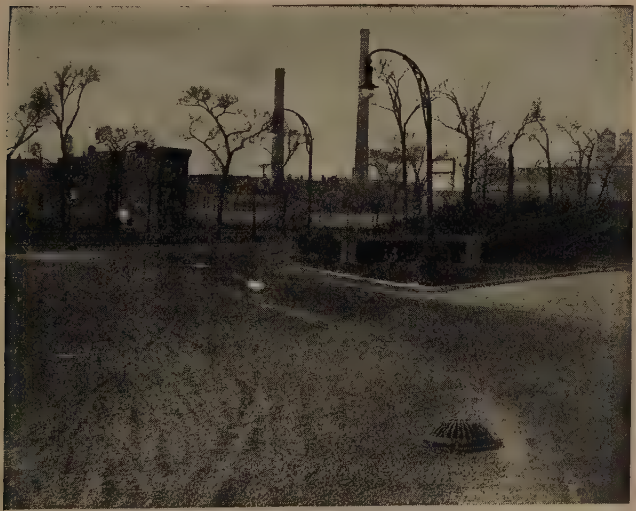


Fig. 8. The "Mushroom" Beacon, as Adapted to Boulevards, Exhibits Green Lights Toward Boulevards and Red Lights toward Intersecting Streets

Highway Crossings

In these days of extensive touring, our highways are often subjected to as much traffic as some city streets. Traffic officers are not stationed at highway crossings and there has been no means of checking the speeding motorist who is attempting to make his 300 miles between breakfast and dinner time. He speeds through all crossings, giving little or no thought to cars that may be approaching at equal speed on crossroads. Flashing electric crossing beacons (Fig. 10) in the path will warn him of dangerous conditions and instill caution.

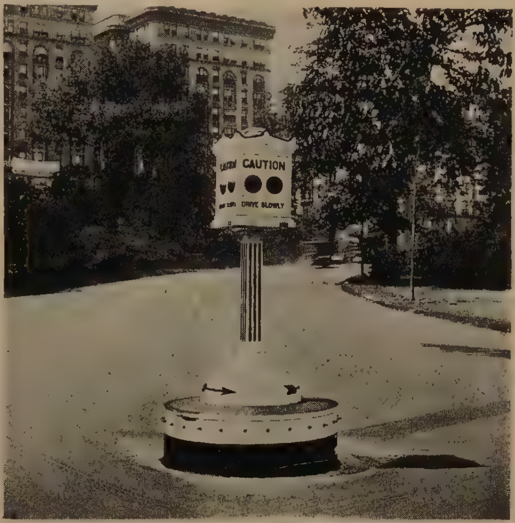


Fig. 9. Another Type of Traffic Signal

It is seldom that alternating current is available so the usual source of energy is the primary battery. Small concentrated filament Mazda lamps when used in efficient reflectors give an excellent daylight signal which can be seen for 1000 to 2000 ft. even under adverse sunlight conditions. A few cells of a 1000-amp.-hr. primary battery are all that is necessary to operate such lamps.

To conserve battery energy a simple device known as a sun valve should be inserted in the circuit either to turn the light on at twilight or to cut in a resistance to reduce the brilliancy of the daylight signal so it will not be glaring at night. The action of the sun valve is entirely automatic, and it functions with the coming and going of daylight. It does not consume any battery energy and depends only on the energy obtained by the absorption of light and its conversion into heat.

The flashers for use on circuits supplied by primary batteries are quite different from those that obtain their current from power lines. Primary battery circuit flashers must be exceptionally economical in their current consumption. Such a flasher has been designed by Mr. Tupper of the Lighthouse Department for use with primary battery installations of buoy lights and other minor lights. This flasher consumes but 20 watthours per year and may be adjusted to give any characteristic to the flash that is desired.

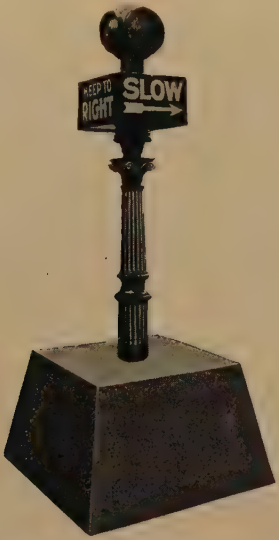


Fig. 10. This Flashing Caution Signal is Operated from Primary Batteries, thus Permitting of Installation where Power Lines are not Available

The financing of the installation and of maintenance costs where they are placed on highways is often accomplished by selling advertising space on the beacon to national advertisers. This practice is not to be recommended.

Railroad Crossings

To avoid any possibility of confusing a railroad crossing with a flashing highway crossing, a new type of automatic flagman has been developed. The signal shown in Fig. 11 is mounted on either side of the crossing. It has six reflectors containing special 6-volt, 1¼-amp. tipless bulb, concentrated filament lamps, and has a red roundel in front of each lamp. The reflectors are arranged in an arc and on the approach of a train the lamps are lighted and darkened consecutively. This presents the appearance of a swinging red lantern across the roadway. It is a daylight as well as night signal that may be seen for 1000 to 2000 ft. and conveys an unmistakable signal "Stop: A train is coming." The energy for this signal may be supplied either by alternating-current power or primary batteries according to its location in respect to power lines. This and other flashing red signals are so effective that the state of Massachusetts has permitted the railroads to remove flagmen on the installation of the signal.

Engineering Service Bureau

To obtain the right system and equipment a great deal of careful study and analysing must be given to the location under consideration. Up-to-date manufacturers of street traffic apparatus are establishing engineering service bureaus to study and arrive at the best solution of problems brought to their attention.

Tourists continually travel through many cities and are apt to be confused by the different color signals for one indication as in New York and Baltimore. Green in New York means "Stop," and in Baltimore it means "Go." The adoption of standard steam railroad colors, where green means "Go," yellow or amber "Caution," and red "Stop" would eliminate this confusion and work toward the elimination of accidents and

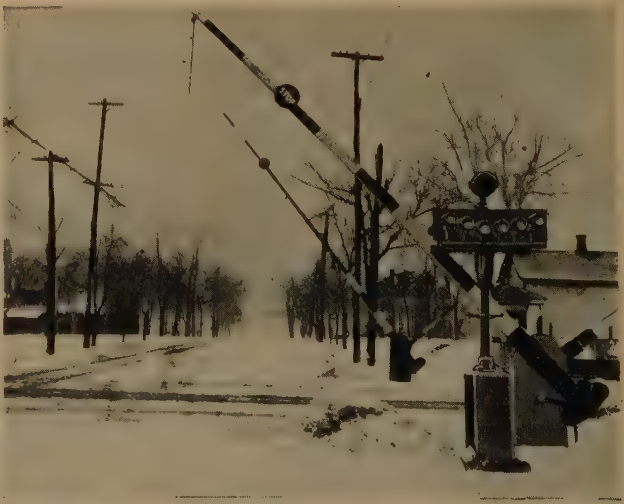


Fig. 11. The Automatic Flagman Presents the Appearance of a Swinging Red Lantern when a Train is Approaching

facilitate traffic movements, which is after all the sole purpose of any traffic system.

In the selection of color lighting signals we must consider the efficiency, range, location, and method of control. To be efficient the beam must not be glaring, it must be of long range and horizontal. The use of concentrated filament street railway headlight Mazda lamps in efficient reflectors gives a range of 2000 to 3000 ft. under the most adverse conditions. The daylight intensity of the beam is reduced at night as a satisfactory daylight signal would be glaring at night.

Education of the Public

It has been found that the public slowly becomes educated and that drivers do obey light signals, even if there is no traffic officer on the corner. The cities having automatic regulation have found it very useful. Pedestrians are more prone to disregard the signals than are car drivers and an extensive educational campaign should be pushed to educate all so that the maximum efficiency of the system can be obtained.

It is necessary to control traffic to expedite its movement and to promote safety. Light signals form the simplest means as only one indication is used both night and day.

The author desires to express his appreciation to the American Gas Accumulator Company of Elizabeth, N. J., for assistance in the preparation of this article.

Time-velocity Characteristics of the High-speed Passenger Elevator

By Bassett Jones

Consulting Engineer, New York City

The public's criterion of satisfaction with an elevator installation is the quality of service rendered. This quality can readily be expressed mathematically as a range of several standard classes of service. A class of service having been determined for a building of given character, housing a given population of given habits, the design of an elevator installation that will meet the requirements with certainty can be determined only by the intelligent application of the data in some mathematical manner, as distinguished from some "hunch" method. This fact is emphasized because the constant increase in population density, the increase in value of land, and the introduction of zoning laws today call for an elevator service which is of a higher standard and consequently even more subject to mistakes in design when determined by any hunch method. In the following article the author discusses the psychology of the elevator passenger, the physiological effect of acceleration and retardation on him, the possible improvements in service through increased car velocity, quicker gate and door operation, better signal systems, and the use of automatic stops. He then treats of the matter of velocity and advances a method of analyzing time-velocity relations which should be of great assistance in intelligently designing high-grade high-speed elevator installations.—Editor.

Question of Service

It is probable that but few of the important office buildings in the larger cities of this country have adequate elevator facilities. Undoubtedly no such building that was erected prior to 1915 is to be included in this list; for had any such building adequate elevator facilities, when built, it would not continue to have such facilities in 1924 unless the building has changed its character or unless the elevator service has been improved.

The above apparently sweeping preliminary statement requires explanation as to the meaning of the phrase "adequate elevator facilities." Furthermore, it is necessary to write down the criterion by which elevator facilities are thus judged to be adequate or inadequate.

The criterion is, of course, the very basis of the method used in determining and selecting elevator equipment. A method was outlined in a previous article.* Like every deductive method it starts with an assumption, namely, an assumption as to the number of people having certain habits that will require vertical transportation in the building. From this point on, to all intents and purposes, the method requires merely ordinary accuracy in the use of the slide rule, together with a reasonable familiarity with the time-velocity characteristics of the available types of hoisting engines and methods of control. If the preliminary assumption is correct and is given proper quantitative values, there is no apparent reason why the results should not be satisfactory. As a matter of fact, where the method has been applied and the results have not been satisfactory, it has been possible always to trace the defect back to the original assumption. An error had been made in population, in the character of the population, or in both.

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*"The Probable Number of Stops Made by an Elevator," General Electric Review, Vol. XXVI, No. 8, p. 583-587.

The method has the distinct advantage of being logical—one can reason about it—whereas the "method of hunches," so commonly applied to the design of buildings and their equipment, results normally in combative disputes as to whether the elevator service actually rendered is, or is not, satisfactory. Obviously, this is taking long chances with the owner's money.

The method of hunches consists in "buttering" the assumptions over one-half to two-thirds of the properly succeeding calculations and lumping the result under the term "common sense." This common-sense method is generally set forth in contrast to the other or "theoretical" method. Sound theory and sound practice are synonymous.

As a matter of fact, most elevator equipments have been proportioned by some "hunch" method—by some empirical or kitchen-clock and thumb-rule method and, commonly, the data used have little or nothing to do with the purpose of the installation. For some unaccountable reason such methods are applied to elevators by people who would never think of applying the same methods to the determination of pumping plants, generating plants, or boiler plants.

This is one reason why *new* elevator equipments are often off-sized. The question why elevator equipments grow off-sized, or grow more off-sized, is another matter. It is for the same reason that horizontal transit facilities grow off-sized. The population served, itself, grows, or moves, or changes its habits. And just as high-grade horizontal transportation may, and generally does, swamp itself by increased population along the line of travel, so does high-grade elevator transportation eventually slow down by over crowding. The principal difference is that more and longer trains, or more cars with trailers, can be added to the horizontal system—or even more tracks may be laid. But the vertical system as usually designed is fixed and is limited to its original capacity.

Since 1915, the average population density of well-located high-class office buildings has increased from 100 or more square feet of yield (or rentable) area per person to 80 or more square feet of yield area per person. Indeed at the present time some such buildings show a population density considerably more than this, even as high as 60 square feet of yield area per person.

Now as to the measure of "adequate elevator facilities." The primary factor is "Service," and service is measured by the general reaction of the passenger. He is either satisfied or dissatisfied with the operation of the elevators, and the service that will satisfy one class of passengers will not satisfy some other class. Here we are faced by the problem of passenger psychology. While the passenger is "the standard automotive package that stacks itself in one tier," some are express packages, and some are freight; some are done up in tissue and tied with silk ribbons, and some come in gunny sacks tied with jute. Each class has to be handled differently, and the preliminary step in any elevator problem is the determination of "class."

For purposes of calculation, service has two aspects: first, the length of time a passenger can be expected to wait for a car, which determines the interval between cars; and second, the length of time a passenger can be expected to remain in a car, which determines the round-trip time. If either are too long, objections to and criticism of the service will result.

With high-class tenancy such as is found in the higher grade office buildings in the larger cities, the range of satisfactory intervals is comparatively short. Such intervals run from 20 sec. for a tenancy consisting of bankers and brokers near or in the financial centers to 30 sec. in the case of professional tenancy where seconds are not of apparent moment. If an interval longer than 30 sec. will give satisfaction, then service is of no material moment.

It is proposed that "standard" intervals be 35, 30, 25 and 20 sec. In other words, if the 20-sec. interval be satisfactory, as it will be in the majority of high-class office buildings, then during the traffic period for which the equipment is selected, a car must on the average leave the ground or main floor every 20 sec.

As was pointed out above, the other service factor is round-trip time. A 35-sec. interval coupled with a round-trip time approximating 210 sec. may be called "casual" service. A 30-sec. interval coupled with 180-sec. round-trip time may be called "low-grade" service. A 25-sec. interval coupled with 150-sec. round-trip time is to be called "intermediate" service. A 20-sec. interval coupled with 120-sec. round-trip time is to be called "first-class" service. Anything better than this is "super-service." Of course, it is possible to find a 30-sec. interval coupled with a round-trip time of, say, 100 sec. This may be first-class service in one case and intermediate in another. A short round trip time may compensate for a long interval, because the last impression left on the passenger's mind is one of quick snappy action.

The statement that the elevator service in a building is inadequate means that during the period of maximum traffic the service is congested and slow—practically casual. It is rare to find an elevator equipment that under these traffic conditions will do better than an average of 30 sec. interval. Records show intervals of 40 to 50 sec. or more, and round-trip time running to 230 sec. in presumably high-grade buildings. But in these cases the "hunch method" had been worked once too often.

A very acute problem is faced when the building is of such dimensions and population that more than one bank of cars must be used, serving different ranges of floors. The question is how to equalize the service in the several banks.

That several banks may be necessary is easily shown by a case. Let there be 1500 people to be taken from the ground floor in 15 min. Let the desirable interval be 20 sec., or 45 departures per bank in 15 min. Of the 20 sec., allowing 5 sec. for operating gates and doors by hand, 15 sec. is loading time, and in this time a *maximum* of 15 passengers can be loaded. If the cars be crowded, then, due to the resulting increased time consumed in loading and unloading passengers, the round-trip time will be increased and, for any given numbers of car, the interval also will be lengthened, and the rush period prolonged. The car size should be based on the maximum rate of passenger arrival. During the 15-min. rush period assumed, it is probable that the traffic flow will exceed the 15-min. average by 25 per cent during 5 min. In terms of statistics, this is the upper quartile of the arrival frequency. Therefore, if the maximum number of passengers to be loaded without increasing the interval time is 15, the average number loaded over the 15-min. period may be taken as 12. Then the bank will dispose of 12×45=540 passengers in 15 min. Obviously, three banks are required and during the rush period each must serve a separate division of the building. Otherwise, intolerable confusion will result.

It is worth while noting here that, since the arrival of passengers is naturally of a random nature, the probable rate of arrival at any time and the time distribution of traffic, may be computed by the calculus of probabilities, the basic data being a "class" scale based on observation. Thus typical traffic data may be established. Such data are found to compare very favorably with measured data.

Assume that one bank of eight cars rated at 600 ft. per min., attained in 5 sec. from standstill, serves from the ground to the 10th floor with an interval of 20 sec. and a round-trip time of 160 sec. It is not practical to operate more than eight cars together as a unit, or as a single bank. A similar bank will serve ten floors above the tenth with a round-trip time approximating 192 sec. and an interval approximating 24 sec. A similar bank will serve from the 20th to the 30th floor with a round-trip time approximating 216 sec. and an interval of 27 sec. Thus, the service in the different banks varies from first class to almost casual.

The only alternate is to increase the number of cars in the high-rise banks unless the round-trip time can be decreased. One means of decreasing the round-trip time is to increase the car velocity and the acceleration. Other means to the same end are greater rapidity of gate and landing door operation through the use of pneumatic or electric door operating devices, greater rapidity of passenger movement by the use of improved signal arrangements, and the elimination of false stops by the use of automatic leveling devices. With hand control, the "false stops" made by the usual operator will amount to at least 50 per cent of the true stops. Remember that when the round-trip time is reduced by an interval the number of cars in the bank required to maintain the schedule can be reduced by one.

A New Problem

The problem of equalizing the service in buildings requiring two or more banks of elevators is made peculiarly acute due to the introduction of the tower type of building. Such buildings are brought into existence by the high cost of the ground on which they stand, and the resulting high taxes. In some locations it is necessary to build as many as 12 to 16 floors in order to break even on the fixed charges accruing from both land and building. Were it not for the rapid increase in building cost per square foot of yield area with the larger number of floors, it would pay to obtain a given yield area by reducing the area per floor and with it the ground area occupied, correspondingly increasing the number of floors. The limit would be the loss in yield area due to the increasing per cent of gross area per floor required for structure and service. The latter includes space occupied by stairs, toilets, corridors and elevators.* The area occupied by elevators increases rapidly with any attempt to equalize service using the same type of equipment throughout.

Even when the ground area is ample, the zoning laws now in force in several cities has the result of progressively restricting the floor area until the general form of the building becomes a parallelepipedal base structure capped by a truncated stepped pyramid, which in turn is capped by a tower of restricted floor area. Such buildings are no longer mere advertising freaks, where the elevator service is of secondary importance, but may be economic necessities if the yield area required to produce a return on the investment is to be obtained within the limits set by the law. The number of floors in such towers will depend on whether the yield area so obtained can be made to pay an adequate return on the investment.

In such buildings the elevator service becomes of primary importance, for the rentable value of the space so gained will depend on the class of elevator service rendered. Thus the elevator equipment becomes a, if not the, determining factor, and presents to the elevator industry a new problem.

In the case of the tower type of building it is probable that, if it is worth while building such a structure, the additional cost of every possible refinement in elevator operation that will reduce round-trip time, and with it the number of cars, will be small compared to the resulting overall operating economies.

It is only by such means that several recently projected structures of this type have been made economic possibilities. One such building, having a tower of approximately 125 ft. square gross plan dimensions, extending above the 17th floor, at a comparatively low rental evaluation of the yield area, showed a good return on the investment up to the 30th floor if the tower could be adequately served at a 20-sec. interval by a bank of eight elevators. To do this required that the cars have a rated velocity of 800 ft. per min. attained in no more than 4.0 sec. from standstill. At such velocities and acceleration car switch operation becomes a practical impossibility. Starts and stops must be automatic, *initiated* by the operator in the car. This requires push button operation. Landing doors and car gates must be opened and closed in an overall time of 1.5 to 2.0 seconds, which is impossible by manual operation. Automatic maintenance of schedule within the interval range is essential, withdrawing and transferring signals if the car gets half the interval behind schedule, and holding the car at the top or bottom landing if it gets half the interval ahead of schedule.

In another similar structure now approaching completion, a bank of six elevators operating on the same basis serve on a 20-sec. interval a tower approximately 80 ft. square gross plan dimensions extending 12 floors above the 16th floor. Eight elevators at the usual rated velocity of 600 ft. per min., attained in 5.0 sec. from standstill, with car switch operation, manual operation of gates and doors, would be required to furnish service at a 30-sec. interval.

The foregoing directly concerns new structures of a special type. Obviously the same methods in whole or in part can be used to improve the elevator service in existing structures. With regard to cost, the investment in the modern high-grade direct drive gearless one-to-one roping traction elevator is today less than the first cost of the corresponding grade of hydraulic elevator some 15 years ago. The difference between the annual costs is still greater.

So much to indicate why it is worth while to discuss the time-velocity characteristics of elevators with a view to determining the form of such characteristics desirable for high-velocity passenger service.

This discussion will not touch upon the method of control required to produce the characteristics desired. Here we are interested solely in the result at the car insofar as it affects the passenger. In the end, it is the passenger who gauges the result, and it is quite useless to arrive at any car velocity attained in any given time from standstill unless the result seems to the passenger both safe and comfortable. In other words, both the passenger's psychology and his physiology must be taken into account.

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* "See Designing Buildings for Economic Operation," S. F. Voorhees, Proceedings Building Owners and Managers Association, 1922.

Velocity

Obviously there is no limit, within the realm of practical possibility, to the velocity at which a car can travel. Velocities as high as 1000 ft. per min. have been discussed. Such velocities impose no mechanical difficulties; and from the viewpoint of the passenger, boxed in a car running on well aligned, well lubricated guides, it seems no different to him whether he be traveling at 200 ft. per min. or 2000 ft. per min. provided only that the velocity be constant. Remember that totally unconscious of the fact, all of us are traveling at this instant relatively to the sun at a velocity vastly in excess of any such values. We carry on many of our ordinary daily customs, and pay little attention to the fact that we may be traveling from New York to Chicago at a velocity approaching 8000 ft. per min. over rails that in an elevator installation would be condemned as too rough for a car speed of 200 ft. per min.

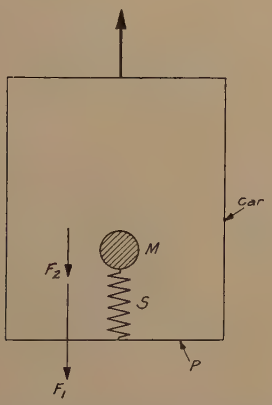

Fig. 1. Diagram Showing the Effect of Forces Set up by Acceleration on the Gravitational Field in an Elevator Car

It will probably be obvious if we make the statement that the limitation in both horizontal and vertical transportation is not in the velocity *per se* but in how the velocity is attained and how standstill is attained. In other words, other things being equal, it is the form of acceleration and retardation that puts the limit on attained velocity.

High-speed vertical transportation differs from high-speed horizontal transportation in one important item. The distance we travel horizontally at a given velocity is not a matter of moment. But, due to the effect of variable air pressure, the distance we travel vertically at a given velocity may be a matter of considerable moment, particularly to people with weak hearts or otherwise sensitive to such changes. Indeed, the problem of acceleration and retardation assumed to be solved, the change in air pressure constitutes the only apparent limit to high-rise high-velocity elevator service. The question is, how fast can we safely drop a man through a given change in air pressure?

At the present time there is no direct answer to this question, but it is extremely probable that no building will be erected in which the limit will be exceeded, or in which it will be economical to run cars at such high velocities that the danger point will be reached. At the present time it is possible to travel 400 ft. vertically at a velocity of 750 ft. per min. with no more discomfort than can be cured by one or two swallows to relieve the pressure on the ear drums.

It is interesting to note, however, that a few immediately successive round trips in such an installation results in violent sea sickness to those who are either not immune or not accustomed to such continuous see-sawing between one air pressure and another, though the difference be slight.

The Physiological Effect of Acceleration and Retardation

Due to the fact that whenever a material body varies its "state" of motion or of rest a resulting force equal to the product of the mass of the body and its acceleration (or retardation) is set up *resisting* the change, it follows that the physical effect produced by either acceleration or retardation is equivalent to the introduction of a gravitational field of force.

If, as in elevator practice, the acceleration and retardation are perpendicular to the surface of the earth, the result in the moving car is equivalent to a change in the fixed gravitational field of the earth. Thus, in Fig. 1, M is a mass representing the passenger's body supported from the car platform P by a spring S, representing the elastic elements of the passenger's bony frame and muscles.

Under the normal gravitational field of the earth the mass M exerts a downward force F_1 on the spring and partly compresses it. If the car accelerates upward, a downward force F_2 is added to F_1 and the spring is still further compressed. So far as the mass and spring are concerned, the result is the same as though F_1, or the gravitational field of the earth, is increased by the amount F_2. If the acceleration of the car be downward, F_2 is negative as regards F_1, and, relatively to the mass and spring, the result is the same as though F_1 were decreased. If the car falls freely, instantly the acceleration will set up a force equal and opposite to the gravitational field F_1, and relatively to the spring the mass M will have no weight. The spring will instantly expand to its full length. Lest there be any misunderstanding, it may be well to state that all of the above is based on ordinary Newtonian mechanics.

Thus, the change in the gravitational field is positive for acceleration on up motion and for retardation on down motion. It is negative for retardation on up motion and for acceleration on down motion. At standstill or at any constant velocity the gravitational field at any time in the car is the same as the gravitational field of the earth at the same place and time. In other words, the gravitational field in an elevator increases when the car is accelerating on the up motion, and decreases when the car is accelerating on the down motion. Also, when the car is retarding on the up motion, the gravitational field in the car increases. Furthermore, when the car is either standing still, or traveling at any constant velocity, the gravitational field in the car is constant, and in *both cases* identical with the gravitational field of the earth at any place the car may be at any moment. The result is the same as though objects of fixed mass in the car vary in weight when the car accelerates or retards.

The result of these changes on the passenger is obvious. When the car is either standing still or traveling at any constant velocity no matter how great, the passenger's body, the various parts thereof, and the supporting muscles are subjected to a fixed and, in both cases, identical stress. Therefore, and as was pointed out in the previous section, it makes no essential difference to the passenger whether the car be standing still or traveling smoothly at any constant velocity in either direction of motion. The discomfort he experiences is entirely due to the bodily adjustments resulting from a variable gravitational field, or, what is the same thing physically speaking, to the varying weight of the different parts of his body, when the car changes its "state" of rest or of motion.

Our problem then is the determination of the way in which the car should be brought from standstill to any desirable velocity and from this velocity to rest with the least possible discomfort to the passenger. The passenger is a deformable semi-elastic body, not a rigid body. The motion of the car is communicated first to the passenger's feet, and then successively to the other parts of his body, each of which due to its inertia resists motion and stretches or releases the attached muscles or tissues. The muscles are set for the weights imposed by the gravitational field of the earth and take time to readjust themselves to the different weights imposed by a different gravitational field.

The resulting movement of the organs and the accompanying pressure of such organs against other parts more rigidly attached to the frame is the cause of discomfort.

Thus, during acceleration on up motion and during retardation on down motion the visceral mass presses downward on the pelvis and on the organs attached to or more directly supported by the pelvis. During acceleration on down motion and during retardation on up motion, the abdominal muscles supporting the viscera are partly relieved of their load, and the resulting reaction of these muscles tends to lift the visceral mass against the pleura, which, unlike the bony pelvis, has no resisting power and transmits the stress upward to the lungs and heart. It is for this reason that a sudden increase in velocity downward or a sudden retardation on up motion induce much more discomfort than equally sudden changes in the reverse directions.

The distribution of mass in, as well as the total mass of, the passenger's body has much to do with the location of maximum stress. A sudden increase in acceleration on the up motion or in retardation on the down motion, if it be severe enough to induce strain, will affect the ankles of a stout person and the back of a thin person. A falling or over speeded car brought to a sudden stop by badly adjusted safeties or buffers will injure the ankles of stout passengers and sprain the backs of thin passengers.

The more abrupt the change in velocity the more abrupt are these physiological changes and the greater the discomfort, particularly in the case of passengers whose muscles are not trained by practice to immediate response.

Physical and mental preparedness has much to do with the discomfort resulting from changes in velocity. A child, who is in no way prepared for such disturbances, feels them very keenly. An older person, accustomed to elevator transportation, feels them much less. Furthermore, if a car is in motion the passenger's body unconsciously prepares itself for a shock. If the car is standing still the passenger's body is relaxed. Therefore the effect of sudden retardation is less than the effect of an equally sudden acceleration.

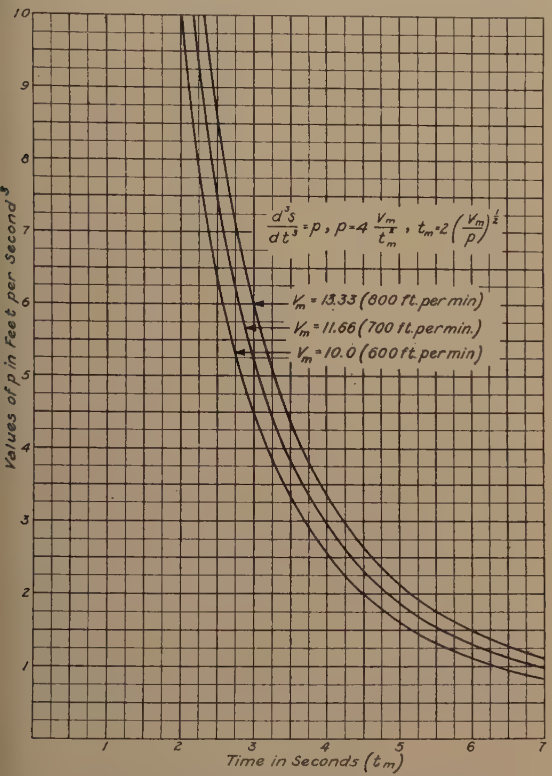

Fig. 2. Curves of Three Maximum Velocities Plotted with Respect to the Time Necessary to Attain Those Velocities at Various Physiological Constants

This may result in making acceleration much more uncomfortable than a considerably greater retardation. Without serious discomfort, it is possible to bring a car from a considerable velocity to rest in 1.5 sec., when the same velocity cannot be attained from standstill without serious discomfort in less than 4.0 sec.

Obviously if high velocities are to be attained in a minimum of time, such results will only be practical when both acceleration and retardation are accomplished with a minimum of discomfort, and this will be accomplished if the gravitational field in the car be changed from one value to another at a constant rate. This requires that the rate of change in acceleration or of retardation be a constant. The only limit to the rate of change is the ability of the muscles to respond uniformly to a constant change in the stress to which they are subjected.

Time-velocity Relations

The above discussion can be formulated as follows:

Let S be the distance traveled in the time t. Let a be the acceleration (or retardation) at the time t. Then the above requirement for constant change in acceleration is satisfied if

$$\frac{d^3S}{dt^3}=p, \qquad (1)$$

where, for want of a better designation, p may be called the *physiological constant.*

It results from equation (1) that the velocity at the time t is,

$$v=\frac{1}{2}pt^2+C_1t \qquad (2)$$

where C_1 is a constant.

In attaining the maximum velocity V_m in the time t_m from standstill, the acceleration first increases from zero to a maximum when the velocity $\frac{V_m}{2}$ has been attained in the time $\frac{t_m}{2}$, and then decreases to zero when the maximum velocity has been attained.

Substitute $v=\frac{V_m}{2}$, $t=\frac{t_m}{2}$ in equation (2) and solve for C_1 as follows:

$$C_1=\frac{V_m}{t_m}-\frac{1}{4}pt_m. \qquad (3)$$

Then equation (2) becomes

$$v=\frac{1}{2}pt^2+\left(\frac{V_m}{t_m}-\frac{1}{4}pt_m\right)t. \qquad (4)$$

Obviously equation (4) represents a parabola of the form $ax^2+bx+C=y$ and in general the vertex is not at the origin. Equally obvious, the only available case is when the vertex is at the origin. Then equation (4) reduces to

$$v=\frac{1}{2}pt^2. \qquad (5)$$

This requires that

$$\frac{V_m}{t_m}-\frac{1}{4}pt_m=0,$$

or

$$\frac{V_m}{t_m}=\frac{1}{4}pt_m.$$

That is, either

$$t_m=2\left(\frac{V_m}{p}\right)^{1/2}, \qquad (6)$$

or

$$p=4\frac{V_m}{t_m^2} \qquad (7)$$

Therefore we are not free in our choice of independent values for p, V_m and t_m. Given any two, the other follows. In practice, generally the value of V_m, or the maximum velocity to be attained, and the value of p in ft. per sec.^{3} will be given for any case. The only possible value of t_m, or the time in which the maximum velocity will be attained, follows as a consequent of equation (6).

The relation between p and t_m for values of V_m equal to 600 ft. per min., 700 ft. per min. and 800 ft. per min. are shown in Fig. 2.

It is probable that the largest value of p suitable for high-velocity passenger elevator service is of the order 6.0 ft. per sec.^{3} Since, as was pointed out in the previous section, retardation may take place in less time than acceleration, the value of p during retardation may be increased probably to 8.0 ft. per sec.^{3} for values of V_m less than 800 ft. per sec. and for ideal control.

It is evident from equation (5) that the proper time-velocity relation during acceleration is a parabola whose vertex is at the origin, that is at the point representing $v=0$, $t=0$, or standstill. The time-acceleration relation will be a straight line through the origin.

Since the acceleration increases at a constant rate, the applied force engaged with acceleration must also *increase* at a constant rate if the acceleration be upward, and if the acceleration be downward the restraining force must *decrease* at a constant rate.

The acceleration, and with it the related applied force, must increase up to the moment when the car has reached half its maximum velocity, and then both must decrease at a constant rate from this point until maximum velocity has been attained when they both become zero. The result is that the whole time-velocity relation between $t=0$ and $t=t_m$ becomes a reversed parabola, the two curves being tangent, or nearly so, at the point

$$v=\frac{V_m}{2},\ t=\frac{t_m}{2},$$

as shown in Fig. 3. The latter part of the curve has its vertex at the point $v=V_m$, $t=t_m$.

During retardation, the same equations hold except that the curves are reversed as shown.

The method of laying out one of these curves may be illustrated by a case. Let $V_m=800$ ft. per min. or 13.33 ft. per sec. Let $p=4.0$ ft. per sec.^{3} Then, from equation (6),

$$t_m=2\left(\frac{13.33}{4}\right)^{1/2}=3.66 \text{ sec.}$$

From these $\frac{V_m}{2}=6.67$ ft. per sec. and $\frac{t_m}{2}=$ 1.83 sec. Equation (5) gives the points on the curve from $v=0$, $t=0$, to $v=\frac{V_m}{2}=6.67$, $t=\frac{t_m}{2}=1.83$, and this curve reversed lies between $v=\frac{V_m}{2}$, $t=\frac{t_m}{2}$ and $v=V_m$, $t=t_m$.

The acceleration is found by

$$a=\frac{dv}{dt}=pt. \tag{8}$$

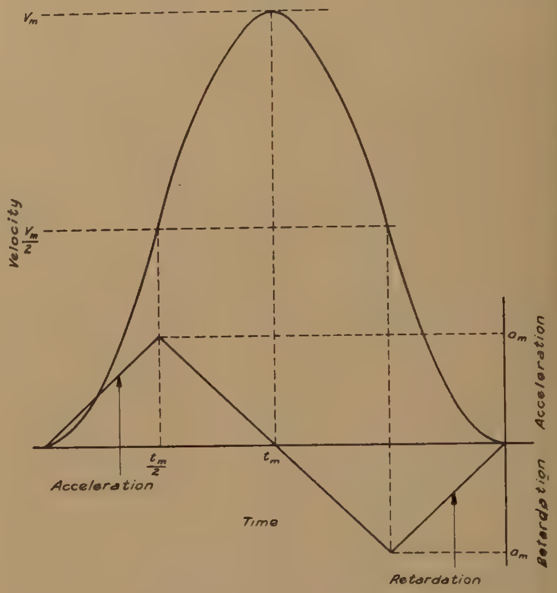

Fig. 3. The Ideal Time-velocity Relation

Then, for this case,

$$a=4\,t,$$

and the maximum acceleration, which occurs when $t=\frac{t_m}{2}=1.83$ sec., is 7.32 ft. per sec.^{2}

The difference between the time-velocity relations as shown and those due to a constant acceleration and retardation (or constant applied force) is shown in Fig. 4.

Note that in the case represented by Fig. 3 the acceleration and with it the applied force required for the acceleration increase at a constant rate from zero to a maximum and then decrease at the same constant rate to zero when maximum velocity has been attained. While, in the case of constant acceleration, the acceleration and with it the related applied force jump suddenly from zero to a fixed value and remain at this value until maximum velocity has been attained when both change instantly to zero. This consideration is somewhat theoretical, because the whole mechanical system considered is not rigid. Friction, and the elasticity of the hoisting ropes must be overcome before the car gets into motion. The result is that, even if the applied force at the rope sheave is constant, the acceleration at the car does not change instantly although under many conditions the change will be very sudden.

If the acceleration or retardation of an elevator even approached a constant, the sudden change at the initial moment from zero to maximum constant acceleration or retardation and the impact of the resulting forces suddenly called into play would produce a marked and probably highly disconcerting disturbance in the passenger's body. The succeeding reverse operation of suddenly changing the acceleration or retardation from a maximum to zero would be equally uncomfortable if not more so.

Consider that if the passenger experienced a free drop the weight of the various parts of his body, relative to his bodily frame, would instantly decrease to zero, and the supporting muscles would be instantly relieved of all stress. Were the passenger not prepared, the result might easily be of a serious nature.

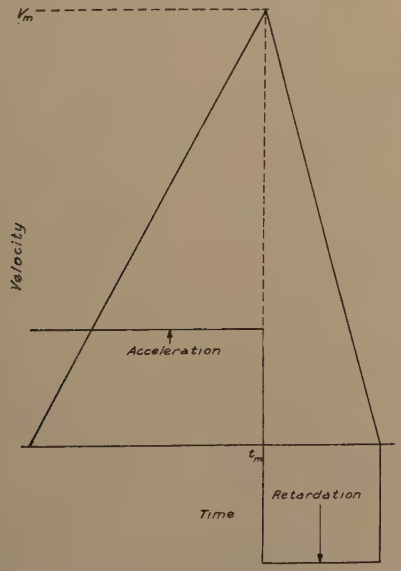

Fig. 4. Time-velocity Relation with Constant Acceleration and Retardation

From these considerations it follows that control devices producing constant acceleration or retardation can not be used in elevator practice unless the acceleration and retardation are of very small amount. Experience indicates that a constant acceleration of even 2.0 ft. per sec.^{2} is uncomfortable during the initial and final periods whereas a maximum acceleration exceeding 5.0 ft. per sec.^{2} has been attained without discomfort by the use of control devices giving a time-velocity relation at the car approximating that shown in Fig. 3.

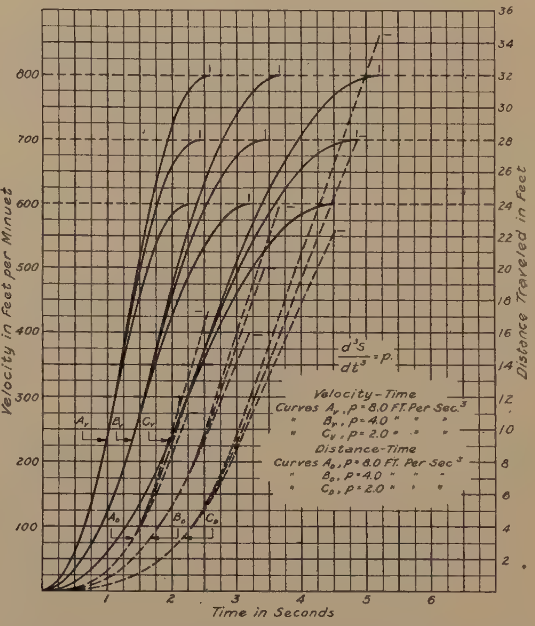

Fig. 5. Ideal Time-velocity and Time-distance Curves for Three Maximum Velocities and Three Physiological Constants

It has often been assumed that the time-velocity relation of elevators approximates that for constant acceleration as shown in Fig. 4. From the foregoing it is evident that this is a false assumption. Passengers would not ride twice in an elevator whose motion even resembles such a condition, for, due to the sudden changes in the weight of their bodies and the resulting reflex action of their muscles at the initial and final moments, the passengers would experience correspondingly sudden shocks independent of the apparently smooth motion of the car platform. Note that where retardation at once follows acceleration, as in Fig. 4, the shock due to the change is greatly increased.

In Fig. 5 are shown a group of ideal time-velocity curves during acceleration for values of $V_m = 600$ ft. per min., 700 ft. per min., and

800 ft. per min., and in each case for $p=2.0$ ft. per sec.^{3}, 4.0 ft. per sec.^{3} and 8.0 ft. per sec.^{3} For each value of p the curves coincide up to $V_m/2$ for each value of V_m.

The distance traveled in each case, also given by the curves, is computed by using the formula

$$S=\frac{1}{6}pt^3 \qquad (9)$$

obtained from equation (5) by further integration. This serves for the range from $t=0$, $v=0$, to $t=t_m/2$, $v=v_m/2$. Beyond this, equation (9) may be put in the form

$$S=V_m t-\frac{V_m t_m}{2}+\frac{1}{6}p\,(t_m-t)^3 \qquad (9)$$

keeping the origin at $t=0$, $v=0$.

In attempting to apply these data, sight must not be lost of the fact that in many cases when the car is making interfloor stops the velocity attained may be considerably less than the maximum velocity. Thus, each group of time-velocity curves in Fig. 5 for any one value of p may be looked upon as the ideal time-velocity relations during acceleration when the car reaches respectively full maximum velocity (800 ft. per min), 0.875 of its maximum velocity, and 0.75 of its maximum velocity before retarding to standstill. The control used must be devised to make these changes at the proper moment in the time-velocity relation without discomfort to the passenger and losing as little time as may be. Only an approximation to the ideal can be expected.

It is also worth while noting that little if anything is gained in traveling time by increased maximum velocity, if the stops made by the car are sufficiently frequent to keep the actual maximum reached much below the maximum attainable velocity. The principal gain that can then be made is by increasing p, or, in other words, by decreasing acceleration time and retardation time, if possible. The gain due to the higher maximum velocities will be marked only where the stops are relatively infrequent or where long "express" runs exist. But this entire discussion originated in a consideration of just such cases. It therefore seems probable that further study of high-velocity passenger elevators along the lines suggested will lead to results of considerable importance for the building art of the near future.

It is hardly necessary to remark that when it becomes necessary to run elevators at such high velocities and increased acceleration, the usual form of operation by a car switch having a multiplicity of speed contacts becomes totally impractical. The time lag between the operator's mind and the response of his hand, and the normal errors and variations in his judgment make it practically impossible for him to attain accurate stops. Under such conditions the number of false stops is unduly increased. If the operator seeks to overcome this by running on low speed as he approaches a landing, he largely nullifies the very characteristics of the equipment through which it is intended to obtain adequate service.

With elevators of the characteristics discussed, it will be necessary to make the stops by automatic means, the stop being initiated by the operator and completed by devices whose operation, once they have been called into service, is entirely outside the operator's control. It must be impossible for the operator to reduce the normal rate of acceleration or of retardation or to operate the car at any velocity less than it will normally attain between stops.

Supervisory Systems for Control and Indication of Remote Power Equipment

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The supervisory control and indicating means described in this article were developed to provide the load dispatcher, or system operator, with a combination of far seeing eyes, long reaching hands, and infallible memory. A higher standard of power and lighting service will follow as a matter of course. The designing engineers first grouped the different layouts of power systems into three classifications and then devised a complete supervisory system for each. These—the distributor system, the selector system, and the cable system—are fully described in the following article. A somewhat shorter description of these systems appeared in the *Electrical World*, September 29, 1923.—EDITOR.

With the extensive development and rapid growth of power networks there has come a great demand for some efficient and economical means to indicate continuously at a central station the condition of the operating units in outlying stations and to have some system by which these units can be controlled from the same point. The advent of the automatic station, the practice of interconnecting power systems, the development of the outdoor switching station, and the natural desire to justify expenditures for new apparatus by material reduction in operating costs are chiefly responsible for this demand.

A supervisory system as applied to the power distribution field may be defined as one which gives a load dispatcher direct control over the rotating or switching equipment of a power network and a continuous visual indication of the operating position of such equipment. Thus, a dispatcher located at a central station in a power system may start and stop automatic stations, open and close oil or air circuit breakers, raise or lower load on hydro-electric generators and have before him red and green lamps which indicate at all times the stopped, running, opened or closed position of the equipment controlled. It is possible to have control without the indication, or indication without control, but a complete supervisory system combines both.

The service requirements are that the system shall be reliable, efficient, contain as few parts and contacts as necessary, be mechanically strong and require as few connecting lines between stations as possible. The systems described in this article have been designed to meet these requirements. Moving parts are enclosed within dust-proof covers and only relays which have successful service records are used.

The automatic station now has been successfully applied in practically all fields of electric power generation and distribution. As a result, the officials of power companies have been discarding the large central station idea and are locating equipment in smaller stations at more economical load centers.

The use of automatic stations not only reduces operating costs but also gives a more flexible power system. This is especially true where a load dispatcher located at some central position has supervision over all the power equipment of the system. A supervisory system may be applied without difficulty to an automatic station as it is only necessary to operate the master controlling device to put the station in or out of service.

The interconnection of power systems, or what is popularly known as the super-power idea, is an advance of the last few years. It is desirable in many cases to connect complete power systems at points remote from central stations and definite knowledge of conditions at these tie points is most important to a load dispatcher. It is necessary at present to synchronize two independent power systems by manual operation. However, there are many cases, other than supervising tie feeders, where an equipment of this type may be applied with desirable results. As an example many contracts between operating companies for the purchase of power are based upon the load-factor or short-time peak load. With a supervisory system both a load dispatcher and a steam turbine operator would know when they had reached their exchange peak and thus be able to pick up sufficient turbine load before the time limit expired. The breaker connecting the two systems also may be opened if the turbine operator is unsuccessful in reducing the load demand.

In an outdoor switching station it is often desired to open or close tie or feeder breakers. By adding a suitable operating mechanism to the breaker in connection with a supervisory system, a load dispatcher may control these at his desk. For example, when a tie breaker trips out on overload, this condition is indicated immediately to the dispatcher who can take quick steps to remedy the trouble, and considerable time is thus saved.

The reduction of operating cost is always an item considered by the commercial companies when adopting new equipment. The advantages gained by the application of a supervisory system of this type are those which make possible unit operation of any or all individual units of the power network. Unit operation means in many cases the elimination of stand-by losses and running-light losses, a saving in time with the corresponding returns for power consumed, and the economical use of electrical equipment.

Better service to the public is assured in districts supplied from automatic stations equipped with supervisory control, as the load dispatcher is continuously informed of the exact conditions existing at all points in the system under his supervision. Should trouble occur on a particular feeder it is indicated immediately and an operator can inform consumers, who make complaint, that the trouble is already under investigation. This saves considerable delay to the consumer and is a much better practice than waiting for a complaint as the initial source of information. In case of an emergency, such as a fire, it is immediately possible for the operator to cut out the feeder supplying the affected section.

In the development of supervisory control equipment to meet the conditions found in service, it was considered advisable to develop three distinct systems, each having its own application in service to a particular condition *and each giving equivalent results* as far as control and indication are concerned.

These systems were designed to cover the following conditions:

(a) A condition where the power system contains a large number of power units located in an outlying station a considerable distance away from the central station. This condition was met by a system using motor-driven distributors and associated apparatus with four connecting line wires from the central station to the outlying station.

(b) A condition where the power system contains several outlying stations spread over long distances with a small number of power units located in each. This condition was met by a system using standard selectors, selector keys, and motor-driven selector keys with three continuous connecting line wires from the central station to all of the outlying stations.

(c) A condition where the outlying stations are located within such a short distance of the central station that it is preferable to install standard telephone cable using one or two wires per switch between the stations rather than employ the distributor or selector system for transmitting the signals between stations.

In the development of these systems it was essential that the design of both the circuits and apparatus should conform in a general way with the requirements already standardized in the well established field of power generation and transmission. The indications to the load dispatcher in order to make the system of practical use are continuous and visual, and are shown by the standard method of red and green indicating lamps. All indications show the position of the power apparatus, whether its operation is due to the automatic functioning of the outlying station equipment or as a result of control from the central station.

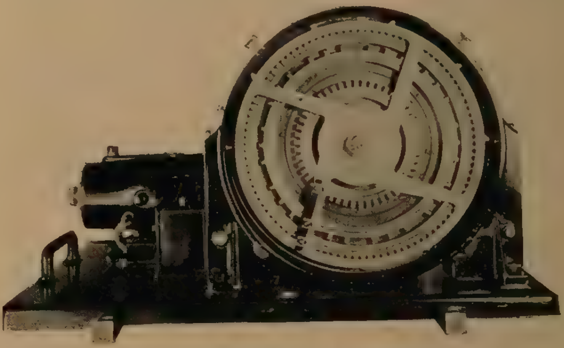


Fig. 1. Front View of a Distributor

For example, to close an oil circuit breaker the dispatcher merely turns a key in the cabinet before him. A red lamp associated with that key lights when the operation has been completed. To open the same breaker a second key is turned and a green lamp lights at the end of the operation. Accompanying all of these indications a bell signal attracts the load dispatcher's attention to the fact that some of the power apparatus has changed in position. It was realized that if the indication was given only for a short interval, such as an audible tone in a telephone receiver or loud speaker while the power units were operating, a simpler system might be used. It was decided, however, that this type of indication would not be satisfactory for the reason that an audible indication would have to consist of a coded tone or a series of different tones. Also, in order that a continuous record of apparatus operation at all times could be kept, it would be necessary for the operator to write down the audible signals as they were received. If the operator was out of range of hearing of the audible indication, the indications would be lost unless some means were provided for recording them.

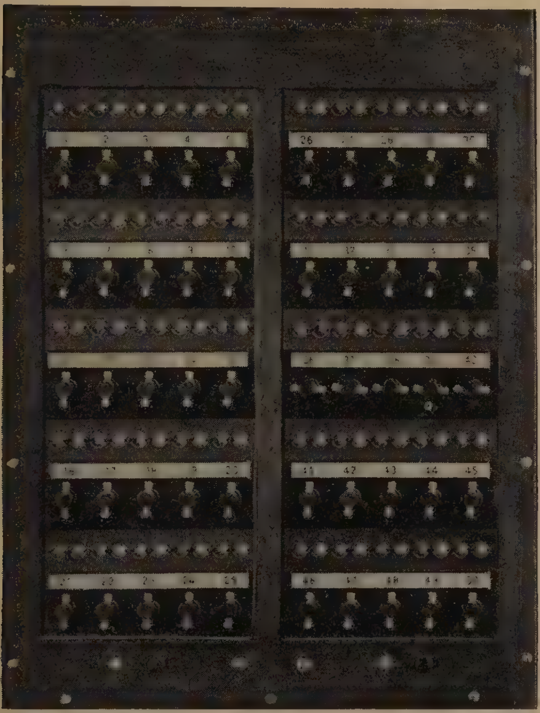


Fig. 2. Dispatcher's Cabinet Unit for Controlling the Operation and Indication of Units in a Power Network

Distributor System

To meet the conditions outlined in paragraph (a) a supervisory system using modified printing telegraph equipment was developed. The standard equipment had some limitations so that a number of modifications in the apparatus and circuits were necessary, although a great many of the mechanical features have been retained. The first distributor system used standard printing telegraph distributors and a combination of coding relays but it developed that so many series contacts were necessary that the relay scheme was found to be unreliable. The next step resulted in an arrangement of distributors without the coding relays and with two connecting lines only, but this system was limited directly to the number of segments on each distributor. As the distributor faces were too small for the addition o the required number of segments, it became necessary to develop the present distributor as shown in Fig. 1. Since this distributor contains a large number of segments and is designed for handling considerable traffic, a synchronizing circuit was found necessary, therefore adding a third wire to the system. The line circuits resulting are one control circuit, one indicating circuit, and one synchronizing circuit, with one common return for each pair of distributors.

For the operation and indication of the units in the power network, the load dispatcher or system operator would have before him a cabinet, Fig. 2, containing one control key and two indicating lamps (one red and one green) for each supervised power unit. The key and lamp circuits are controlled through a system of polarized relays and the distributor so that the operation of any one of the 50 keys on the dispatcher's cabinet will operate the corresponding controlling unit in the distant station through similar relays and a distributor controlled by impulses over the connecting lines. In a like manner the operation of any power equipment at the distant station will be indicated over the same connecting lines to the dispatcher. The arrangement of the control keys and indicating lamps resembles as near as possible, but in a miniature form, a standard power switchboard. The indicating lamps are arranged in pairs, one pair being associated with each key and one or the other of the lamps of each pair is lighted at all times. Similarly other pairs of lamps are arranged to show a number of other operations taking place at the distant station without the manual aid of the operator or dispatcher.

Fig. 3 shows a typical apparatus cabinet used in both the dispatcher's office and the outlying station. The cabinet is made of sheet steel with doors opening at the front and rear. In the upper section is mounted the distributor while the lower section contains polarized relays, one for each supervised unit.

Fig. 4 is a schematic diagram showing in the simplest way the principle of operation of the distributor system. The upper diagram is the controlling circuit from the dispatcher's station to the distant station. The center diagram is the indication circuit from the distant station to the dispatcher's station. The lower diagram is the control circuit used entirely for synchronizing the rotation of the brush arms. Keeping in mind that the three circuits are contained in one pair of distributors, it will be understood that the three brush arms shown are in reality carried by one arm on each distributor, rotating at a given speed.

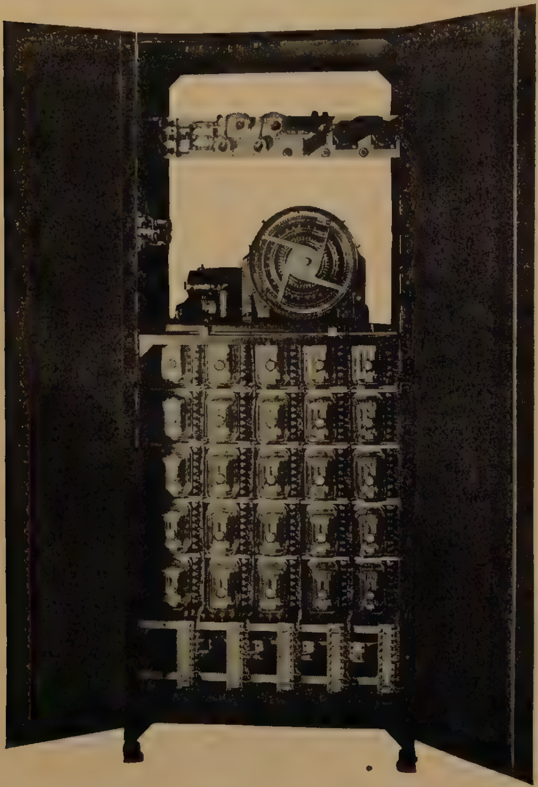


Fig. 3. Typical Apparatus Control Cabinet Used in Both the Dispatcher's Office and the Outlying Station

For the synchronized operation of the brush arms of both distributors, control segments and collector rings are provided to send a series of positive and negative impulses over the line wire and through the windings of the release magnets of the distributors located at the opposite end of the line. Thus, the two release magnets being in series will operate and release the brush arm of each distributor simultaneously. Since the teeth on the brush arm are in alignment with the control segments, the release magnet will be energized before the brush carrier teeth engage with the latches, provided the distributors are operating in synchronism. If, however, the two distributors are not running in synchronism and if one brush arm should lag behind the other, the arms will be brought into step each time the teeth on the brush arm engage with the release magnet latch. In other words, the brush arm which is running the faster will be stopped at the release magnet latch and held until the slower arm reaches the corresponding position.

Assuming that the pair of distributors is operating as described, positive or negative current originating at the dispatcher's key will be transmitted to the sending segment over the connecting line wires to the receiving relay at the distant station. The receiving relays being polarized will take a position corresponding to the impulses received from the sending keys at the dispatcher's station as the distributor brushes pass over the corresponding segments on the distributors. Each supervised unit at the distant station is provided with an auxiliary switch operated in either one of two positions by the functioning of the equipment to which it is attached. In this way positive or negative current from a local battery is placed on the sending segments of the distributor at the distant station in the same manner as that described for the operation of the keys at the dispatcher's station. A similar series of impulses will be sent back over a separate line wire to the dispatcher's station for the operation of the receiving relays at that point. The operation of these receiving relays will change the indication given by the red or green lamps.

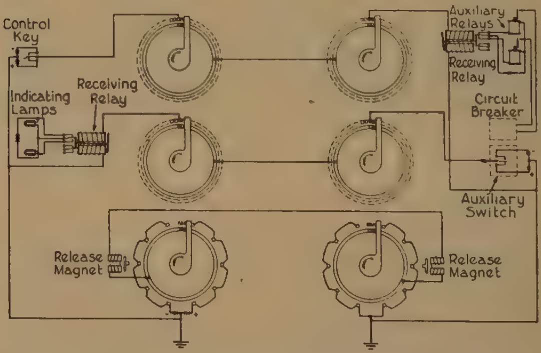


Fig. 4. Schematic Diagram in Simple Form showing the Principle of Operating the Distributor System

The distributor brush arm rotates at a speed of one revolution in five seconds or 12 revolutions per minute. This means therefore that all operations of control and indication will be accomplished within a maximum period of five seconds. Since the brush arms are rotating continuously, control and indication impulses will be repeated once during every revolution, thus assuring extremely efficient operation of the receiving units at both stations.

Any interruption of the line wire is shown at once by a line indicating lamp provided in the dispatcher's desk cabinet. This lamp normally flashes on each incoming signal (that is at the rate of 10 per second) and if this lamp goes out or stays lighted it indicates trouble on the line or of the battery supply at either the distant station or the central station. Also if either of the distributors for any reason stop or fail to transmit the sending and receiving impulse, this will be indicated to the load dispatcher by this lamp. Jacks and switches are provided in each line wire to aid in testing.

If any switch or other apparatus at the distant station has changed in position during any interruption of the line wire or trouble on any part of the supervisory system, then as soon as the trouble is cleared all indicating lamps will at once take the position of the switches at that time.

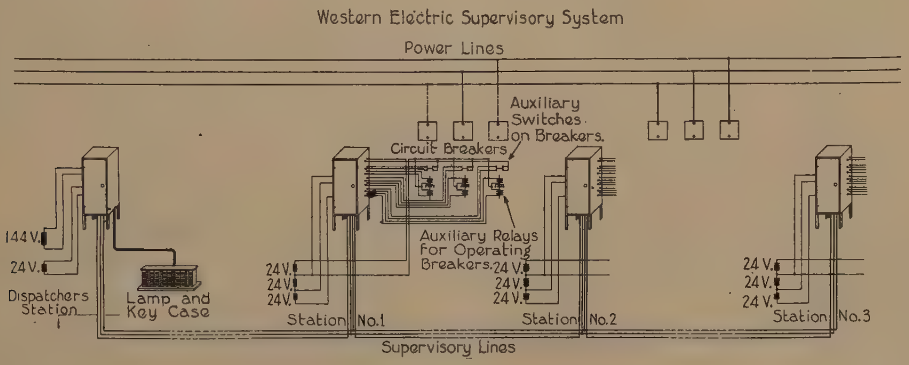


Fig. 5. General Layout of a Supervisory System

All apparatus has individual covers and in addition is mounted in such a manner as to be accessible for inspection and readily removed if desired. No marginal current or voltage devices or timing devices are used. All relay contacts are large and have ample contact pressure to insure reliability.

If the battery source fails for any reason at any of the stations, no false operation will take place as all relays for operating the switches at the distant station and all relays for operating the indicating lamps at the dispatcher's station remain in the position last operated. As an additional precaution against a false switch operation due to failure in apparatus or lines, the circuit arrangement is such that the control circuit for operating the switches is inoperative except when the dispatcher desires to operate a switch.

Selector System

As outlined in paragraph (b), when a power network contains a dispatcher's station and a number of distant stations scattered over a wide territory, the selector system is applicable and the three line wires may be run continuously throughout the system.

By the use of standard train dispatching selector equipment the control feature for operating the power units was comparatively simple. This meant only an adaptation of the standard calling circuit used in train dispatching systems. However, to produce the visual indication by the standard practice of lighting a red or green indicating lamp, an automatic sending device located at the outlying station was necessary. The original automatic sending device for the indicating circuit was designed as a single-unit automatic motor-driven key, one key being required for the two indications of each power unit. In order to utilize one motor and one reduction gear combination and to apply a local lock-out circuit together with a clutch and latch arrangement for preventing the overthrow of the impulse wheels, the present four-unit automatic motor-driven key was developed as shown in Fig. 6. This device has a capacity for sending in eight indications for the "open" or "closed," "start" or "stop" positions of four power units. The mechanism is driven by a 24-volt direct-current motor which is operated whenever there is an indication to be sent in to the dispatcher's office. It would be possible to develop a system requiring two rather than three connecting lines if the positive lock-out feature had been waived. However, it was the opinion that a positive lock-out circuit was necessary so that if two or more power units, either in the same or different stations, operated simultaneously, the indicating signals would be transmitted to the central station in sequence.

In this system, a general layout of which is shown in Fig. 5, the dispatcher will have before him a lamp and key cabinet, Fig. 7, similar to the one described and shown in Fig. 1, except that in this case there are two keys for each supervised unit. Associated with each pair of keys are two indicating lamps, one red and one green. The keys of the left-hand side are associated with the red lamps, and the keys on the right-hand side with the green lamps. This arrangement

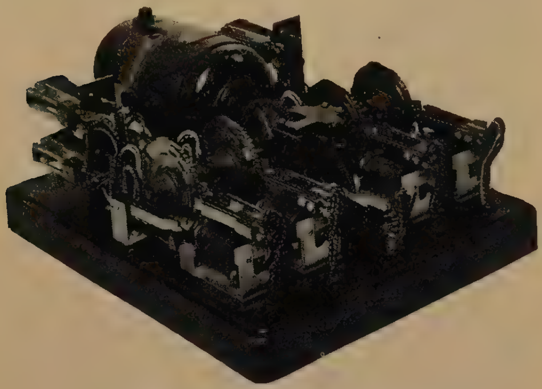


Fig. 6. Device with a Capacity for Sending in Eight Indications for the "Open" or "Closed" "Start" or "Stop" Positions of Four Power Units

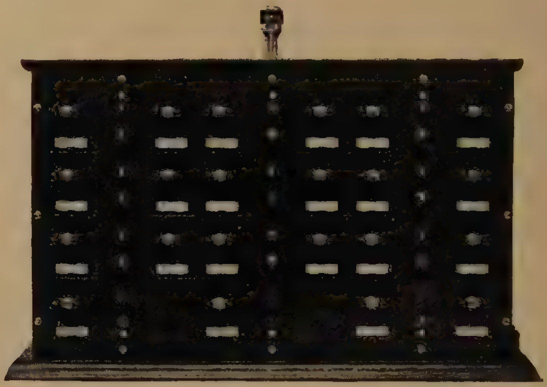


Fig. 7. Operator's Lamp and Key Cabinet

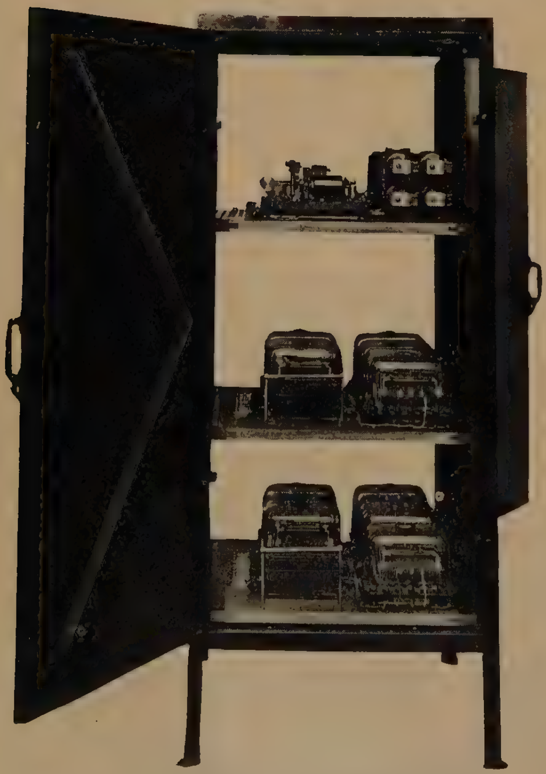


Fig. 8. Apparatus Cabinet at the Dispatcher's Station

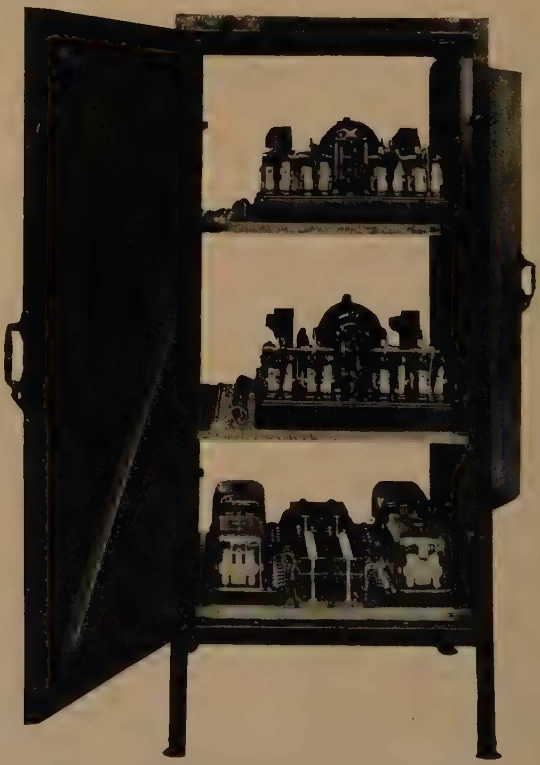


Fig. 9. Apparatus Cabinet at the Distant Station

enables the operator to control at will any of the apparatus in the outlying stations and gives him a visual indication at all times of not only the operation of the apparatus but the final position taken by each unit. For instance, if the operator wishes to open a circuit breaker he turns the designated key in the key cabinet and when the unit has functioned the indication changes in the usual manner. In addition to this the apparatus at the dispatcher's station is so arranged that any change in the operating position of any of the units at the outlying station will light a pilot lamp located on the top of the cabinet and ring the alarm bell, calling the attention of the load dispatcher to the fact that there has been a change in the circuit conditions.

Fig. 8 shows the apparatus cabinet at the dispatcher's station. This cabinet is made of steel with front and rear hinged doors and is arranged with slides to take the apparatus shelves as shown. On the top shelf is mounted the common control apparatus while on the next two shelves are mounted the selectors for receiving indications from the outlying stations. Fig. 9 shows the apparatus cabinet used at the distant station and is similar to that used at the dispatcher's station. In this cabinet are mounted the motor-driven selector keys for originating the indicating impulses and the selectors for receiving the control impulses sent from the dispatcher's station. Both apparatus layouts are arranged in units of four.

When the dispatcher operates one control key to open or the other control key to close a designated power unit, a train of impulses will be sent out over the connecting lines to the outlying station, and the selector which has the same code setting as the sending key will move to the operating point and close a contact which in turn energizes the auxiliary relay governing the operation of the power unit. The operation of this power unit through its auxiliary contact will start up one of the automatic motor-driven keys and release a corresponding code wheel. The operation of this code wheel will send a series of impulses to the dispatcher's station. The selector at the dispatcher's station, set for the same code as that being sent by the impulse wheel, will step to the operating point, energize a local relay and give the indication in the usual manner. The operation is the same for each supervised unit, but the equipment is so interlocked that no incoming signals can occur while the dispatcher is operating his keys and but one indication can be sent in at a time. Should several breakers either in the same station or different stations open simultaneously, indications will be stored and sent in to the dispatcher's office in a definite order.

All apparatus in this system except the motor key has been used on all railroads of this country and many railroads in foreign countries for several years in their train dispatching systems. It has given such reliable service and low maintenance together with long life that it has been adopted as standard equipment.

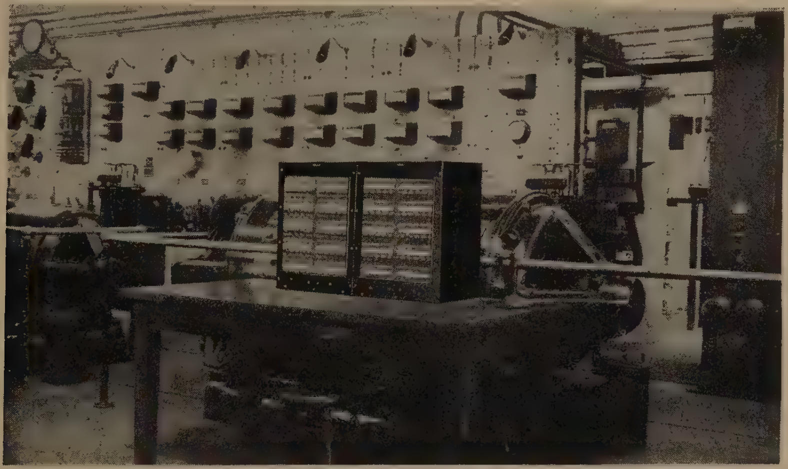
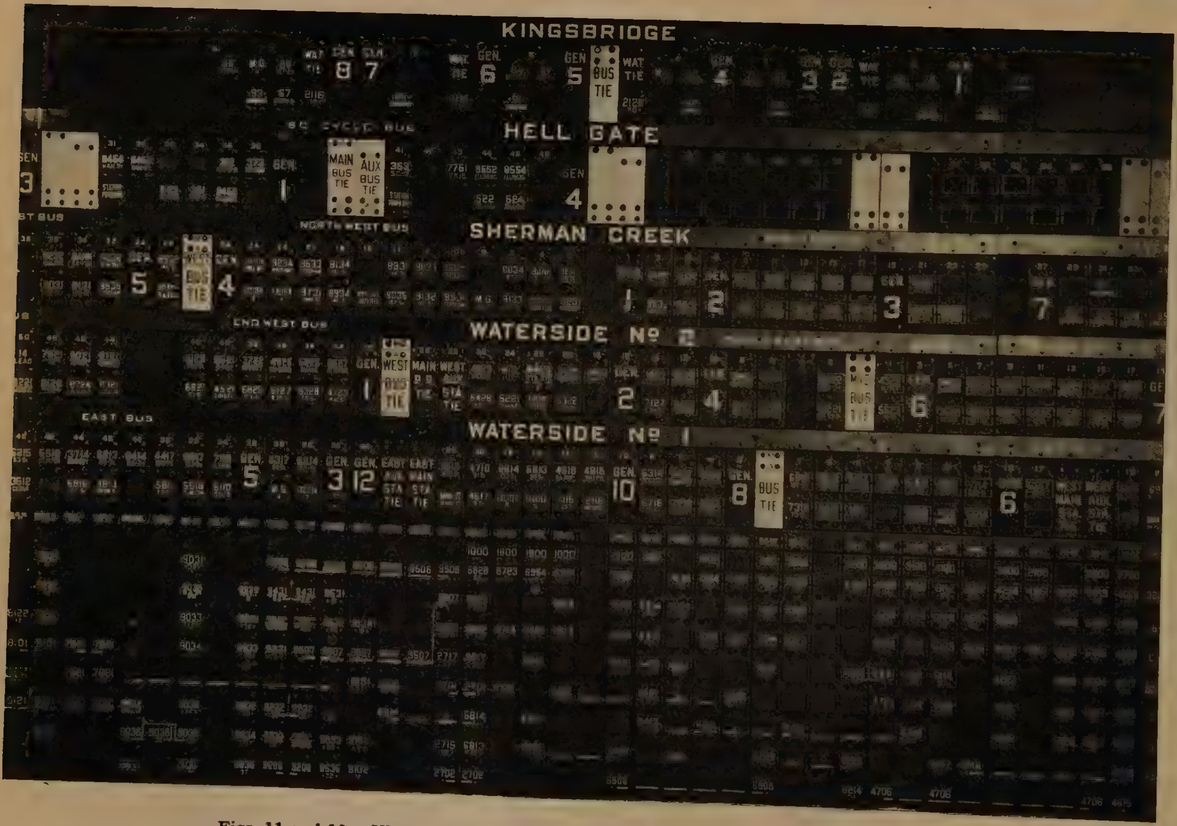


Fig. 10. A Dispatcher's Cabinet as Applied to the Control and Indication of Switches in Two Outlying Stations



Figs. 11 and 12. Views of the Load Dispatcher's or System Operator's Pilot Board at the Waterside Station of the New York Edison Company

Cable System

Where the central station and the outlying stations are located within a short distance of each other it was considered advisable to develop a system using multiple-conductor lead-covered telephone cable in place of two distributors. This requires one wire per switch for control and one wire per switch for indication. The terminal apparatus at both stations is the same as that used with the distributor system with the exception of course that no distributors are necessary.

Operating Batteries

Originally it was intended to operate the majority of the equipment in both the distributor and selector supervisory systems by alternating current supplied directly from the buses of the various stations. However, it was decided that since the supervisory systems are most valuable when trouble is occurring on the power networks, a separate battery source for the operation of the supervisory system would be more reliable.

The potentials required for the operation of the distributor system are derived from 120-volt motor-generators or batteries located at both ends of the system. A center tap is taken off from each to furnish 60 volts positive and 60 volts negative. The batteries required for the operation of the selector system are one 144-volt battery at the dispatcher's station and one 72-volt battery divided into three equal parts at each of the outlying stations. The constant battery drain in no case exceeds one ampere. In the cable system a 120-volt battery with a center tap is required at both the dispatcher's station and the outlying station. In this case the current drain will be 0.008 amp. for each indication and 0.008 amp. for each control of a power unit. A 24-volt source of either alternating current or direct current is required for lighting the indicating lamps in each of the systems. The maximum current drain is 0.040 amp. for each unit indicated at the dispatcher's station.

Some Typical Installations

Fig. 10 shows the dispatcher's cabinet as applied to the control and indication of switches in two outlying stations. The equipment shown is that of the Malden Electric Company at Malden, Mass., located in the Malden Power Station. The two outlying stations are located at Medford and Everett. Figs. 11 and 12 show the load dispatcher's or system operator's pilot board of the New York Edison Company located at the Waterside Station. The section of the board marked "Hellgate" is an application of the cable system and indicates the open and closed position of approximately 200 circuit breakers at the Hellgate Power Station. The section of the board marked "Sherman Creek" is an application of the distributor system and indicates the open and closed position of approximately 186 circuit breakers.

All these installations have been in service for over a year and the maintenance has been normal; these installations have thus proved that the supervisory systems under actual operating conditions are entirely reliable and also of great value in the operation of the power equipment.

Effect of Rotation on Stress Distribution in Electric Railway Motor Pinions

By A. L. Kimball, Jr.

Research Laboratory, General Electric Company

A study is being made of the stresses in railway motor pinions by the Coker photoelastic method, which has been completely described in the following issues of this magazine: 1920, Nov. p. 870, Dec. p. 966; 1921, Jan. pp. 73 and 82, Mar. p. 222, and May p. 455. This work is being carried on under the supervision of the Research Laboratory of the General Electric Company, with its own apparatus, by Prof. Paul Heymans at the Massachusetts Institute of Technology. Acknowledgment is due to Messrs. W. Dietz and T. H. Frost for their coöperation. The following article records the latest results.—Editor.

One of the first commercial applications in this country of the Coker photoelastic method of determining stress distribution has been in connection with an investigation of railway motor pinions by the General Electric Company. With this method a knowledge of the stresses in railway motor pinions is obtained by direct measurements taken on celluloid models. The results should furnish an independent check on the accuracy of the purely mathematical calculations, and eliminate much of the guesswork that arises from complicated actions too intricate for direct computation.

The first stage of this investigation covered certain cases in which the celluloid model pinions had a static couple applied to them and the stresses in them determined while the pinions were stationary. The next stage of the work is reported in this article and differs from the foregoing in that the analysis is extended to include the stress determination in a pinion while it is actually rotating under load. The results are of a preliminary nature and the study is being continued.

Method Used

In order to measure, by means of the photoelastic apparatus, the stress at a given point in a rotating pinion which is shrunk onto a shaft and which is transmitting torque, it is necessary to obtain a stationary image of the tooth while it is in motion. Since the colored image is continually changing as the tooth passes through the field of view, there is only one instant during each revolution of the pinion when the stress distribution in a particular tooth repeats itself. Therefore, by using an electric spark to furnish illumination at just this instant every revolution, a permanent stationary image can be obtained by projection onto a screen. This can be analyzed or can be photographed on a color plate provided the sparks recur a sufficient number of times.

A kenotron rectifier set, Fig. 1, was used to produce the high-voltage static electricity necessary to supply the recurring sparks. Fig. 2 shows a diagrammatic plan of the essential parts of the apparatus. *H* and *I* are the celluloid model pinions examined, and are identical to each other. They are about 7 in. in diameter and ¼ in. thick, and of the design shown in Fig. 4. The pinion *H* is driven by means of the induction motor *A* through the gear wheels *C* and *D*, and the chain drive *F*. The celluloid pinion *H* drives the celluloid pinion *I* against an adjustable torque load applied to the brake wheel *J* and measured by means of a dynamometer. The recurring spark, from which the illumination is obtained for the stationary image, takes place across the gap *U* at the focus of the condensing lens *T*. The resulting beam of light is polarized by the Nicol prism *Y* and is transmitted through the gear wheels under investigation *H* and *I*, is analyzed by the Nicol prism *Y′*, Fig. 3, and the image is projected onto the screen *V′*. The color distribution in this image corresponds to the stress distribution in the model. If a photograph is to be obtained, the screen *V′* is replaced by the photographic plate. The spark is timed by the control gap *R*, which consists of two knobs, the right-hand knob being on a short arm and the left-hand knob being on a long arm, Fig. 2, this latter arm revolving eight

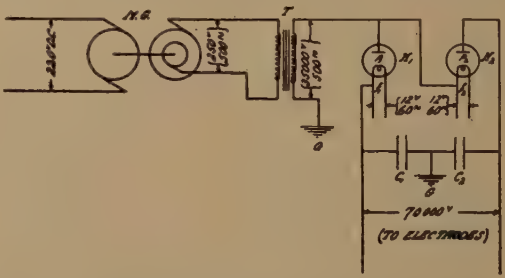


Fig. 1. High-voltage Kenotron Rectifier Connections

(*M.G.*, motor-generator; *T*, transformer; H_1 H_2, kenotron tubes; f_1 f_2, filaments of tubes; p_1 p_2, plates of tubes; C_1 C_2, glass-plate sheet-iron condensers; *G*, ground.)

times as fast as the former and swinging past it in the opposite direction. Thus the long left-hand arm swings around eight times before it comes opposite the short one again, permitting a discharge at the main gap, and illuminating the gear pinions *H* and *I*. Since the long arm moves eight times as fast as the gear wheels *H* and *I*, the spark recurs at almost exactly the same point of contact of these gears for each revolution. For example, if the spark should occur when the knobs of the gap *R* were ¼ in. out of line, the gear wheels would be hardly ¹/₄₀ in. out of position owing to the multiplying action of the gears. Since this case is considerably exaggerated compared with the irregularities of the discharge actually obtained, it can be seen that with this arrangement the point of contact would probably never be more than ¹/₅₀ in. away from the position required for an exactly repeating image.

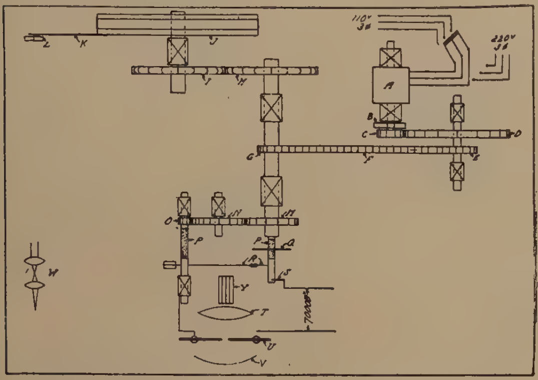


Fig. 2. Diagrammatic Plan of Driving Arrangement for the Gear Models

(*A*, 2-h.p. 3-phase induction motor; *B*, band brake; *C*, *D*, spur gears; *E*, sprocket; *F*, chain; *G*, sprocket; *H*, celluloid gear pinion; *I*, celluloid gear pinion with expansion ring; *J*, band brake with dynamometer; *K*, sighting arm; *L*, fixed index; *M*, *N*, *O*, spur gears; *P*, fiber shaft; *Q*, fiber shield; *R*, arms; *S*, brush; *T*, collecting lens; *U*, electrodes; *V*, reflector; *W*, telescope; *Y*, polarizer and analyzer.)

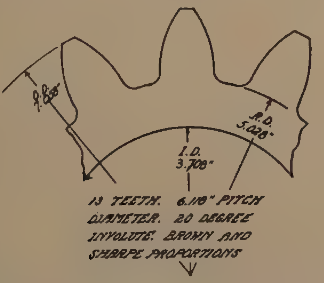


Fig. 4. Tooth Form of Pinion Subjected to Photoelastic Analysis

By this method colored photographs were obtained of the repeating image which were as perfect as though the gear wheels were not revolving at all.

In order to obtain an image of the particular point of contact desired, the time of spark occurrence was so adjusted that the repeating images of the arm *K*, Fig. 2, carried by the wheel *J* lined up exactly with the stationary index *L*.

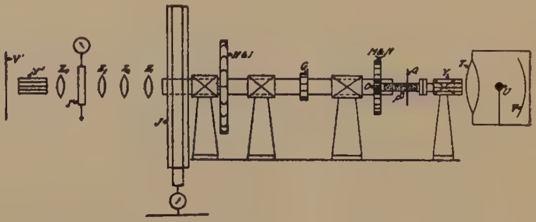


Fig. 3. Diagrammatic Elevation of Arrangement shown in Fig. 2, with Photoelastic Apparatus Included

(*I'*, comparison member for stress determination; *V'*, screen or photographic plate; Z_1, Z_2, Z_3, Z_4, lenses. Other letters as in Fig. 2.)

Results Obtained

The results of the tests on rotating pinions obtained thus far are shown in Fig. 5. This curve shows the per cent increase in stress in the revolving pinions over the stress in these pinions while stationary, for speeds from zero to 1250 r.p.m., the torque load being the same in both cases. In both cases the radial pressure at the bore was 845 lb. per sq. in., and the resulting torque was 125 in.-lb., corresponding to a tractive force of 164 lb. per in. of face. The right-hand ordinate of Fig. 5 gives the maximum stress observed in the celluloid pinions at a point of high stress, and this is translated to the case of a steel pinion, taking a ratio of 29.7 to 1.

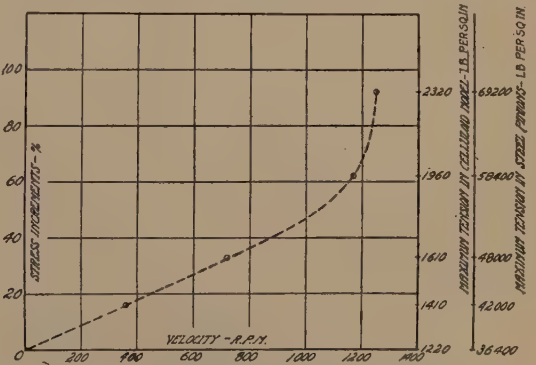


Fig. 5. Increase of Maximum Tension in Celluloid Model and Steel Pinion with Increasing Speed

Charles Proteus Steinmetz and Complex Quantities

We have received the following letter from Mr. E. W. Rice, Jr., asking us to publish a letter he has received from Dr. A. E. Kennelly. As we believe this correspondence is self-explanatory, we publish both Mr. Rice's and Dr. Kennelly's letters without further comment.—EDITOR.

December 31, 1923.

Mr. J. R. Hewett,
Editor, GENERAL ELECTRIC REVIEW.

Dear Mr. Hewett:

I enclose herewith a letter from Dr. A. E. Kennelly of Harvard University and the Massachusetts Institute of Technology which I would be glad to have you publish. In this letter you will note that Dr. Kennelly calls attention to a mistake which I inadvertently made in crediting Dr. Steinmetz with the original discovery of the application of complex quantities to alternating-current problems. At the time I wrote my appreciation of Dr. Steinmetz I was unaware of Dr. Kennelly's prior publication.

I agree with Dr. Kennelly that Dr. Steinmetz "did so much for us that it is not necessary to make it more," and therefore in thus giving proper credit for Kennelly's prior work, we are not in any way detracting from the value of Steinmetz's contributions.

Very truly yours,
[Signed] E. W. RICE, JR.

HARVARD UNIVERSITY

December 28, 1923.

Dr. E. W. Rice, Jr.,
Honorary Chairman,
General Electric Co.,
Schenectady, N. Y.

Dear Dr. Rice:

I have read, with interest and pleasure, your article on "Charles Proteus Steinmetz," appearing on pages 796-799 of the GENERAL ELECTRIC REVIEW for December, 1923, Vol. XXVI, No. 12. I have great admiration for the work of the late Dr. Steinmetz, and heartily endorse the general tribute you have therein paid to his accomplishments.

There is, however, one statement on page 797, which I think is, by oversight, excessive, and which I beg permission to point out, because your writings properly carry so much weight and authority in the engineering world. Your article attributes to Dr. Steinmetz the discovery of the application of complex quantities to alternating-current problems. No one can deny that Dr. Steinmetz contributed very greatly to the development and use of the complex-quantity method of treating such problems; but I believe the record will show that he did not originate or discover that method.

I believe that the first application of complex numbers and their vector arithmetic to technology was published by me in my paper on "Impedance," read April 18, 1893 (*Trans. A.I.E.E.*, April, 1893, Vol. X, pp. 175-216). Prior to that date, I believe that complex quantities were only known to mathematicians as a branch of pure mathematics. The operator $\sqrt{-1}$ was of course well known, and was named j by Bedell and Crehore, in their book on "Alternating Currents," published in March, 1893, but the use of complex quantities in computation was not known at that date, so far as I am aware. In my paper of April, 1893. I published the discovery of Ohm's law extended to cover the alternating-current circuit by the use of complex quantities.

On page 186 thereof, after various geometrical examples of the method, the following statement appears:

> "Any combination of resistances, non-ferric inductances, and capacities, carrying harmonically alternating currents, may be treated by the rules of unvarying currents, if the inductances are considered as resistances of the form $pl\sqrt{-1}$, and the capacities of the form $\frac{-1}{kp}\sqrt{-1}$, the algebraic operations being then performed according to the laws controlling 'complex quantities.' "

Dr. Steinmetz was not present at the New York meeting, when the paper referred to was read. The printed discussion, however, contains a contribution stated, on page 227, as having been communicated by him, and at the top of page 228, he states, as I understand him, that the method published in my paper was new to him in connection with alternating-current circuits. So that, unless I am mistaken, Dr. Steinmetz himself admitted my priority in this matter.

Dr. Steinmetz's first paper on the subject was, I believe, before the International Electrical Congress of Chicago, in August, 1893, "Complex quantities and their use in Electrical Engineering," (Proc. Int. El. Congress, A.I.E.E., 1894, pages 33-74 and also 24, 25). In that remarkable and classical paper, he expanded the method considerably, and showed, for the first time, that the method includes also Kirchoff's laws. He did not touch upon the history of the subject in his paper; or he would doubtless have referred to my earlier paper of April in that year.

Dr. Steinmetz did so much to develop the use of complex numbers that it is not surprising that there should be a general opinion that he originated their application and first introduced them into electrical engineering. At least one American book, on the laws of Physics, thus attributes both Ohm's law and Kirchoff's laws to Dr. Steinmetz in the alternating-current field. To Kirchoff's laws I believe every one will admit that he is entitled.

No discussion of the history of this subject can properly omit reference to Oliver Heaviside's papers, which gave so notable an advance to our knowledge of alternating currents. Prior to 1893, I believe that neither vector quantities nor complex numbers are disclosed in his published papers; but he undoubtedly came near to them ("Electrical Papers," by Oliver Heaviside, MacMillan Co., 1892, Vol. II, page 355, "*On Resistance and Conductance Operators and their Derivatives, Inductance and Permittance, especially in Connection with Electric and Magnetic Energy*"). The term "impedance" is here defined; but without vector- or complex-quantity relations.

In conclusion, I hope that nothing presented in this letter will be considered as detracting from the great value of Dr. Steinmetz's numerous contributions to the literature of the alternating-current circuit. He did so much for us, that it is not necessary to make it more.

Yours respectfully,
[Signed] A. E. Kennelly.

A TRIBUTE TO CHARLES PROTEUS STEINMETZ

H. F. Parshall, D. Sc., M. Inst. C. E.
Consulting Engineer

Salisbury House,
London Wall,
London, E. C. 2

December 19, 1923.

The Editor,
General Electric Review,
Schenectady, New York.

Dear Sir:

I should like to contribute a word to the tributes already paid to the late Mr. Steinmetz.

It will be recalled by some that when Mr. Rice arranged for Mr. Steinmetz to come to Lynn he was placed in my department known as the Calculating Department.

The work that Mr. Steinmetz elected to give his particular attention to was entirely in the matter of alternating-current applications. The principle of commutating machines had been largely solved, the laws of the magnetic circuit were definitely understood through the classical papers of Hopkinson and the nature of the hysteresis loss was also well understood, the factory being provided with apparatus for the measuring of hysteresis losses in different kinds of iron and steel plates. The calculation of commutating machines had become a definite science so far as the calculating of heat loss was concerned and the proportion of radiating surfaces to allow for the radiation of heat. The problem then as now was as to getting the greatest output from a given amount of material with no sparking at the commutator. Steinmetz did not profess any special knowledge or interest in commutating machines. He regarded that part of engineering science as more or less in a state of standardization. The same state of affairs did not apply to alternating-current machinery. Everything referring to the specific theory of this was certainly in a very hazy condition, especially in the case of induction motors. The general theory of induction motors was understood but how to determine the specific performance was quite another matter. I remember very well the first machine that Steinmetz tackled and the diagrams and equations that he produced. These certainly were a very great advance: they were, however, so far as Steinmetz was concerned only preliminary and he went on developing the diagrams and formulae until finally the induction motor design assumed the same definite form as had previously existed in the case of commutating machines.

Likewise Steinmetz pointed out the lines on which alternating-current generator design should proceed. I believe the work of Reist, Foster and others was greatly stimulated by the mathematical assistance given by Steinmetz. The same applied, although to a more limited extent, to transformers.

From my own knowledge I believe Steinmetz's greatest assistance to engineers in the earlier days was in the direction of showing the effect of the conditions obtaining in external circuits as to self-induction, capacity and resistance on the specific performance of different classes of machines.

Speaking personally I regard Steinmetz's strongest point as his ability to suggest to others new methods and promote the imagination in the direction of overcoming difficulties. In my experience I have come in contact with men of the best engineering minds, but I should say without doubt that Steinmetz was entirely by himself in his ability to stimulate mental activity and suggest new methods.

Undoubtedly Steinmetz's physical deformity was a great embitterment to him but he was always a most congenial companion and a thoroughly good sportsman so far as his physical abilities permitted him to go. I think it is not too much to state that Steinmetz was absolutely unique in many of his mental characteristics and that there is no one in sight to take his place.

Yours faithfully,
[Signed] H. F. Parshall.

LIBRARY SECTION

Condensed references to some of the more important articles in the technical press, as selected by the G-E Main Library, will be listed in this section each month. New books of interest to the industry will also be listed. In special cases, where copy of an article is wanted which cannot be obtained through regular channels or local libraries, we will suggest other sources on application.

Balancing

Balancing High-speed Fans. Greene. Arthur L.
Iron Age, Dec. 6, 1923; v. 112, pp. 1512-1513.

Coal Storage

Factors in the Spontaneous Combustion of Coal. Hood, O. P.
Mech. Engng., Dec., 1923; v. 45, pp. 691, 694.
(Considers methods of storage of coal.)

Drafting Practice

Scheduling and Progress-recording of Drawings. Hoffman, Irwin.
Mach., Dec., 1923; v. 30, pp. 296-297.

Electric Drive—Steel Mills

Rolling Mill Equipment. Taylor, W. E., and Raeburn, C. E.
Elec'n., Nov. 30, 1923; v. 91, pp. 600-602.
("Some present-day problems in design and construction discussed and elucidated.")

Electric Locomotives—Testing

Electric Locomotives Tested at Erie.
Elec. Rwy. Jour., Dec. 8, 1923; v. 62, pp. 968-970.
(An account of tests of a G-E high-speed locomotive for the Paris-Orleans line, and of a freight locomotive for the Mexican Railway.)

Electric Motors—Speed Control

Speed Regulation of Strip and Bar Mills.
Elec'n., Nov. 30, 1923; v. 91, pp. 606-608.

Electric Testing

Rubber Gloves Tested for 10,000 Volts.
Elec. Wld., Dec. 8, 1923; v. 82, pp. 1175-1176.
(Methods used by the Consumer's Power Co., Jackson, Mich.)

Electric Transmission

Interconnection in New York State.
Elec. Wld., Nov. 17, 1923; v. 82, pp. 1013-1016.
(Abstract of transmission lines committee report, Empire State Gas and Electric Association.)

Electric Transmission Lines

Line and Substation Costs.
Elec. Wld., Dec. 8, 1923; v. 82, pp. 1159-1163.
(Comparison of costs of 66-kv., 110-kv. and 132-kv. systems. Includes tables of cost data.)

Fatigue of Metals

Notes on the Fatigue of Metals. Lessells, J. M.
Mech. Engng., Dec., 1923; v. 45, pp. 695-696.

Feed Water Heaters

Economy Characteristics of Stage Feed-water Heating by Extraction. Brown, E. H., and Drewry, M. K.
Power, Dec. 4, 1923; v. 58, pp. 896-898.
(Abstract of paper before the American Society of Mechanical Engineers.)

Fires, Electrical

Hazard of Flammable Dust Shown in a Recent Explosion of Aluminum Powder. Price, David J., and Baker, Robert M.
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